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# COMBUSTION

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Main Switchboard and Control Table, Rouge Plant, Ford Motor Company

## Boilers, Economizers and Air Heaters
## Their Economic Limitations

By F. H. Rosencrants

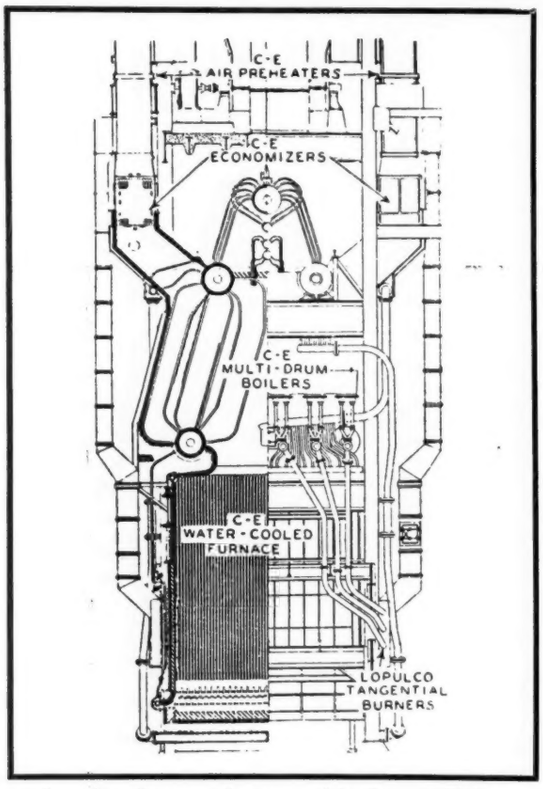
## Performance of Modern Steam-Generating Units

By C. F. Hirshfeld and G. U. Moran

Other Articles in This Issue By

G. C. DERRY • JOSEPH KEENAN • GEORGE RAMSEY • P. B. PLACE

# PULVERIZED FUEL

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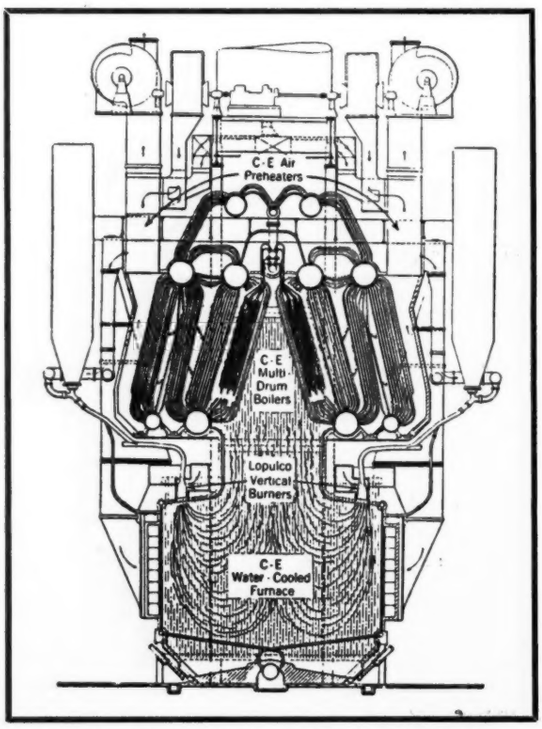
***as applied to one of two duplicate units—the largest super-pressure boilers in the world.***

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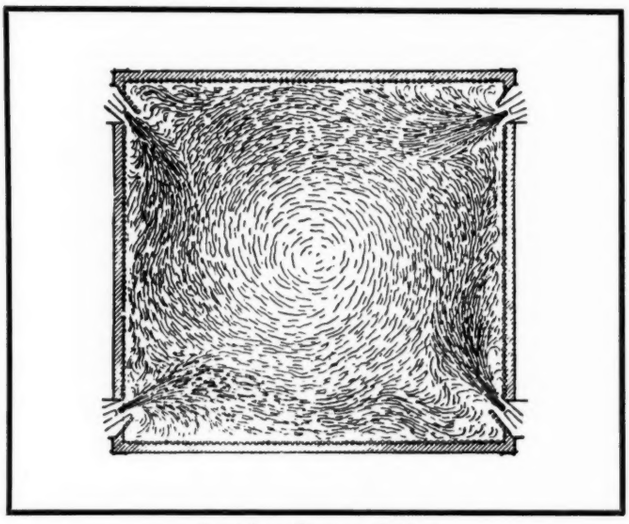
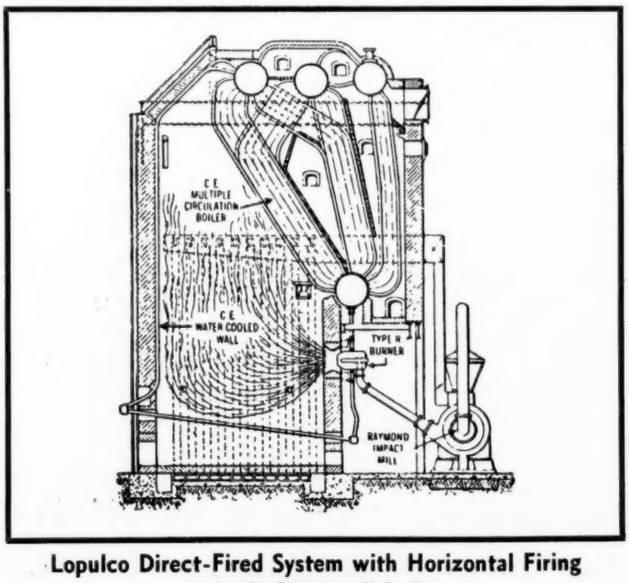


**Lopulco Corner Firing**

***Diagrammatic plan view of furnace opposite showing turbulence and intensive mixing effect.***

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# COMBUSTION

VOLUME FOUR • NUMBER SIX

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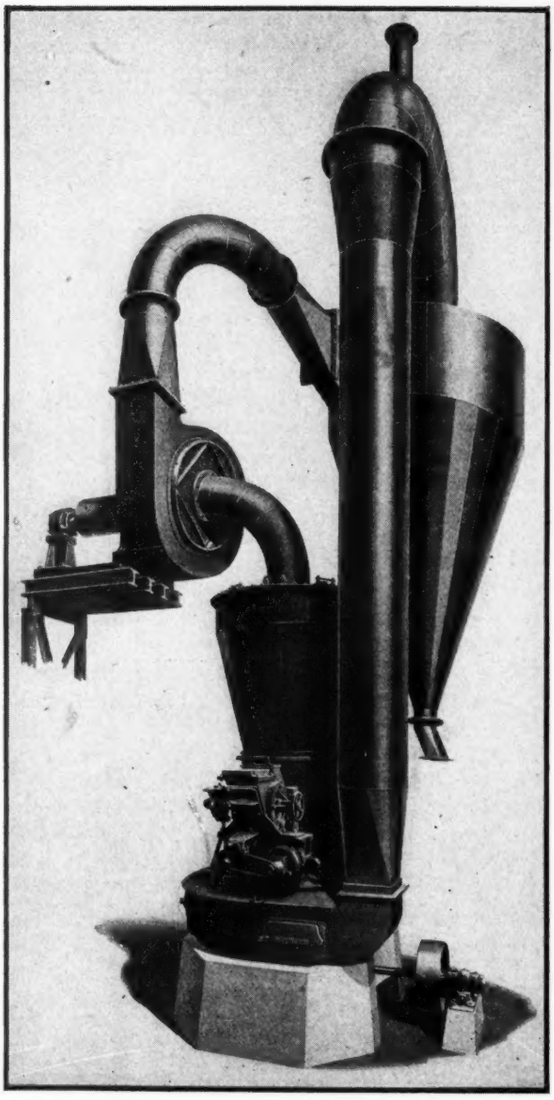

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# Commentary by Joseph H. Keenan

## B.t.u's. and Kilojoules

We have been told that the British thermal unit is the amount of heat required to raise the temperature of one pound of water through one degree fahrenheit. But the meticulous engineer and the sceptical scientist ask, through just which degree? We delve into textbooks in search of that one answer which an exact science always gives to a specific question. We find instead a singular plurality of answers. One book stipulates 32 deg. to 33 deg., another 59 to 60, another 50 to 51. If all the various one degrees that have been used in defining the B.t.u. were placed end to end they would reach from ice to boiling water and back to ice again.

Our difficulties do not end here for even if we decide on a particular one degree our B.t.u. is of little use until we know its value in terms of other energy units such as the foot-pound or the kilowatt-hour. For this we must depend upon the experimental physicists who have laboriously added measured quantities of energy to water and noted the temperature rise. Of course no two physicists ever got the same answer, and it might almost be said that no two physicists ever investigated the same B.t.u. Variety is the spice of life, but heat units have been seasoned beyond digestibility.

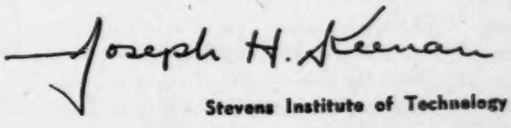
There are other kinds of British thermal units which I have not yet mentioned. The mean B.t.u. is defined as 1/180th of the amount of heat required to raise the temperature of 1 pound of water from 32 deg. fahr. to 212 deg. fahr. Originally a pressure of one atmosphere was prescribed. Then Osborne at the Bureau of Standards measured the enthalpy, or total heat, of water about to boil (saturated liquid) all the way from 32 deg. to 212 deg. He found that he had measured the value of the B.t.u., if he were allowed to define the B.t.u. to suit himself. Since he had not measured heat added, but enthalpy, and since he had not worked at one atmosphere but along the saturation line he found it necessary to invent a new mean B.t.u., which was 1/180th of the difference in enthalpy between saturated liquid at 212 deg. fahr., and saturated liquid at 32 deg. fahr.

In science, as in politics, periods of confusion are periods of opportunity for those who know what they want. If mechanical engineers, for instance, could formulate their concept of the function of a heat unit, in all probability that concept would become the philosophy of the unit of the future. If a well defined engineering concept does exist, we should find it underlying the analytical methods of as typical a field as power plant engineering.

Every existing steam table tabulates enthalpies in terms of either calories or British thermal units. The values are deduced largely from experimental measurements which consist essentially of producing a change in the state of water or steam by adding to it a measured quantity of electrical energy. It is true that the transition of this energy usually takes the form of work or heat, but it is measured as electrical energy. Thus the specific heat at constant pressure of superheated steam has been measured at Munich by adding a measured amount of electrical energy to a flowing stream of steam and noting its temperature rise.

The engineer who designs a turbo-alternator wishes to find from the steam tables the output of his machine in kilowatt-hours. How fortunate then that the experimenter has produced his steam table material in terms of just that kind of unit! But we have yet to reckon with the author of the steam tables who carefully divides each enthalpy value as he enters it in his table by the number of electrical units which constitute his favorite heat unit. Thereafter every use of the steam table involves the undoing of the author's pedantic exercise in division by a pragmatic operation in multiplication. And so it comes about that the electrical equivalent of the heat unit looms large in engineering computations.

The engineering concept appears to be easy to satisfy. Leaving the enthalpy values of our steam tables in terms of the electrical units in which they are measured removes all uncertainty as to the magnitude of the unit and saves wear and tear on the engineering slide rule. Enthalpy may be expressed as so many kilowatt-hours or so many kilowatt-seconds. The kilowatt-second, or kilojoule, is the more convenient unit of the two. It is easy to remember that the number of kilowatt-seconds in a kilowatt-hour is 3600, the same as the number of seconds in an hour. Also, since the kilowatt-second is within 5 per cent of the magnitude of a B.t.u., its adoption would occasion no change in our rule-of-thumb arithmetic. The specific heat of water will still be about one, the latent heat will still approximate one thousand. We shall lose nothing in convenience by the change. We shall gain much in certainty.



Stevens Institute of Technology

# EDITORIAL

## Performance of Modern Steam Generating Units

ONE of the most valuable technical papers that has come to our attention in a long while is to be presented under the above title at the forthcoming annual meeting of the American Society of Mechanical Engineers by C. F. Hirshfeld and G. U. Moran, both of the Detroit Edison Company. This paper, reprinted, except for three tables of detailed data, in this issue of COMBUSTION, is the final report of investigations extending over a three-year period from July 1, 1928, to July 1, 1931. During this period data were collected concerning the design, performance and availability of 250 modern boiler units located in 61 stations.

As the authors point out in the first part of the paper, it is possible today to predict the thermal performance of a steam generating unit with close accuracy. Such performance balanced against the cost of the installation permits comparison of the economic values of the various designs being considered and is indicative of the savings possible where new equipment is to replace or supplement existing equipment. However, in order to measure fully the economics of a contemplated installation it is necessary to know the extent to which the equipment can be relied upon to give continuous service. There is no satisfactory method of obtaining this information except by studying the actual performance of similar units over a considerable period of time. The difficulties of securing sufficient data for such a study are apparent and it is for this reason that the work of Messrs. Hirshfeld and Moran deserves commendation as a particularly valuable contribution.

The summaries of the data, presented in Tables 4, 5, 6, 7 and 8, crystallize the results of the investigation and give an excellent picture of the performance of modern steam generating units over a considerable range of conditions as to fuel, size and type of unit, pressure, temperature, method of firing, etc. Table 9 contains a resume of the major causes of outage and may be regarded as a recapitulation of the principal design and operating problems confronting the field today. Concentration on the major causes of recurrent outage will over a period of time disclose ways and means of lessening the effect of these causes on continuity of service. The information published in this table should facilitate progress along these lines.

As in every study of this sort there is a danger in applying the conclusions indicated to particular cases without a full appreciation of their relative value and accuracy. In this connection the comments of the authors with respect to the weight to be attached to various conclusions indicated by the data should be studied carefully.

The authors regard the period in which the investigation was made as one of rapid and constant development, and state as their belief that this condition still obtains and will continue to for some time to come. Consequently many abnormal conditions exist which will tend to confuse and distort the efforts of the investigator. They find, however, that even in this transitory stage modern steam generating units may be relied upon for use from 82 to 86 per cent of the time. These are average figures in a number of cases, availability ratings of well over 90 per cent were reported.

In analyzing the factors which determine the performance of steam generating units, it should be realized that type and design of equipment are of secondary importance with respect to reliability. The materials and methods of equipment manufacture, the care with which equipment is installed and placed in operation and the ability and interest of the operating staff are the factors which principally influence availability ratings.

## A Service to Unemployed Engineers

THE editorial in our November issue, in which we stressed the opportunities inherent in the fields of combustion and steam generation, came to the attention of an engineer who had specialized in this field for some years past and whose ability was recognized by the assigning to him of many important responsibilities. During the past year he lost his position and has not been able to find another. Naturally he felt that he had reason to question whether the need for well-trained men in this field was as real as our editorial indicated. Of course we explained to him that we were discussing the opportunities of the field in a broad sense and not with respect to such abnormal times as these.

All of which suggests to us the possibility that we may be able to render a valuable service to our field by bringing the qualifications of highly capable engineers, temporarily unemployed through no fault of their own, to the attention of the many plants in various parts of the country that even in these times may be seeking such men. Accordingly we have decided to contribute a column or a page, as may be needed, in each issue for this purpose. Any unemployed engineers who have had considerable training and experience in the design and operation of steam power plants may avail themselves of this service by sending us a brief resume of their qualifications and the work they have done in the past. We invite readers who know of such individuals to put them in touch with us.

# The Design of Steam Generating Plants

PART V

## Boilers, Economizers and Air Heaters —Their Economic Limitations

By F. H. ROSENCRANTS, Consulting Engineer
Combustion Engineering Corporation

**What are the conditions and principles which govern the application of an air preheater, an economizer or both in connection with either an existing or a new boiler installation? When one or the other type of surface is justifiable, which is the more economical? How does the design of boiler affect the problem and how should the surfaces be proportioned to assure the most economical results? The author states the principles governing these important decisions and offers yardsticks for the relative evaluation of the different forms of heat recovery surface. His article is a valuable guide to engineers confronted with these problems.**

IN the study of the most economic boiler-air heater-economizer combinations, the limitation of each type of equipment as applied to the particular case in hand should receive first consideration. Figs. 1 to 4 are designed to facilitate such a study.

In Figs. 1 and 2 approximate minimum differential temperature between outlet gas and saturated steam temperature and between outlet gas and inlet feedwater temperature respectively have been assumed. Economic conditions in terms of fuel cost, load factor, plant cost, etc. may dictate a somewhat higher differential but they will not dictate a very much lower value, as cost of equipment for a further reduction mounts up rapidly.

In Figs. 2 and 4 the feedwater temperature shown approaches the maximum which will be encountered in steam-electric plants wherein the feedwater is heated to its final temperature with steam extracted from a high pressure stage of the main turbine. With a lower feedwater temperature, the outlet gas temperature may be reduced by a corresponding amount.

An outlet gas temperature of 300 fahr. at maximum continuous rating is fixed as a minimum below which corrosion difficulties due to condensation, particularly at low rating, are likely to become troublesome.

In Figs. 3 and 4 an inlet air temperature to the air heater of 80 fahr. is assumed. A variation of 20 or 30 deg. in this temperature will not affect the general conclusion to be drawn from the study.

The rise in air temperature is predicated upon 85 per cent of the air component of the flue gas passing through the heater, a value which at full rating represents first class practice and is seldom exceeded. At reduced ratings the percentage will be materially reduced.

In this study the superheater is not considered as in all cases it is so placed that it takes the place of boiler heating surface and in no case influences the application of air heaters and economizers.

From a study of Fig. 1 it will be noted that at 200 lb. pressure the gas temperature from the boiler may be reduced to about 500 fahr. while at 1600 lb. it is 727 fahr. The corresponding dry flue gas losses above that which would be sustained at the minimum recommended temperature of 300 fahr. are 5.2 and 11.2 per cent of the heat in the fuel respectively.

Fig. 2 shows the extent to which the losses of Fig. 1 may be reduced by the addition of an economizer. Counterflow of gas and water is assumed. It will be observed that the minimum outlet gas temperatures attainable with an economizer still show a loss above that sustained by 300 fahr. of 2.2 and 6.4 per cent of the heat in the fuel at 200 and 1600 lb. pressure respectively. It must of course be kept in mind that a lower feedwater temperature will result in a correspondingly lower possible exit gas temperature. The gains realized by heating the feedwater to high temperature with extracted steam from the main turbine are such, however, that it is not economical to reduce the feedwater temperature for the sake of obtaining a higher boiler plant efficiency.

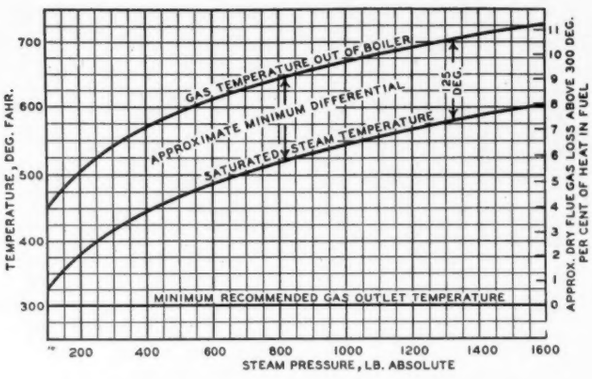

GAS TEMPERATURE OUT OF BOILER
APPROXIMATE MINIMUM DIFFERENTIAL
SATURATED STEAM TEMPERATURE
25 DEG.
MINIMUM RECOMMENDED GAS OUTLET TEMPERATURE
TEMPERATURE, DEG. FAHR.
APPROX. DRY FLUE GAS LOSS ABOVE 300 DEG. PER CENT OF HEAT IN FUEL
STEAM PRESSURE, LB. ABSOLUTE

**Fig. 1—Heat recovery possibilities with boiler only.**

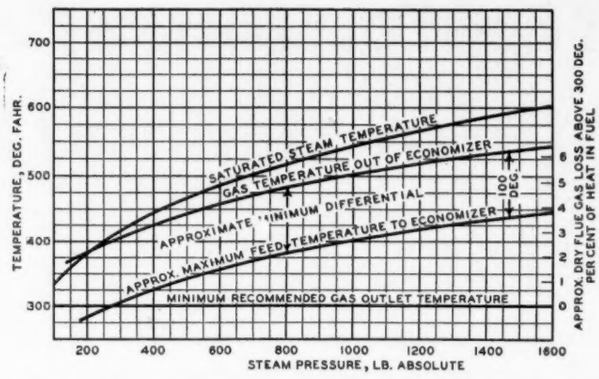

SATURATED STEAM TEMPERATURE
GAS TEMPERATURE OUT OF ECONOMIZER
APPROXIMATE MINIMUM DIFFERENTIAL
100 DEG.
APPROX. MAXIMUM FEED TEMPERATURE TO ECONOMIZER
MINIMUM RECOMMENDED GAS OUTLET TEMPERATURE
TEMPERATURE, DEG. FAHR.
APPROX. DRY FLUE GAS LOSS ABOVE 300 DEG. PER CENT OF HEAT IN FUEL
STEAM PRESSURE, LB. ABSOLUTE

**Fig. 2—Heat recovery possibilities with boiler and economizer.**

Fig. 3 shows the possibility of heat recovery by the application of an air heater to the boiler of Fig. 1. As will be noted the gas outlet temperature for the whole range of pressure is reduced to the recommended minimum of 300 fahr. The differential temperature between exit air and inlet gas runs from 155 deg. at 200 lb. pressure to 95 deg. at 1600 lb. pressure. The outlet air temperature runs from 350 fahr. at 200 lb. to 630 at 1600 lb. pressure. To obtain such results in a high pressure design, requires very large air heaters, more than can be economically justified in many instances. But it is a practical combination and many such are in operation over the whole range of pressure.

Fig. 4 shows the result of applying an air heater to the boiler-economizer combination of Fig. 2. Here the outlet gas temperature from the air heater is reduced to the recommended minimum of 300 deg. fahr. over the whole range. The differential temperature between outlet air and inlet gas is much better than in Fig. 3 being nearly 200 deg. at 200 lb. and 150 deg. at 1600 lb. and hence requires a smaller increment of surface to obtain the final increment of gas cooling and the corresponding increment of efficiency, than is the case with the boiler-air heater combination of Fig. 3.

The application of an air heater is governed by several factors other than considerations of thermal economy. Its installation is dictated in many instances by a demand for hot air for drying coal in the coal pulverizing units. In stoker-fired installations the limit of temperature which can be used successfully is from 300 to 400 fahr. depending upon the type of stoker, kind of coal, rate of firing, etc. For high efficiency in such cases the combination of boiler, economizer and air heater as per Fig. 3 will be required. For pulverized fuel, oil, or gas fired jobs the extreme air temperatures shown in Fig. 3 are entirely practical. The fact, however, that even for such applications some use boiler, economizer, and air heater and many others only a boiler and an air heater would indicate that relative costs are not so far apart. This is particularly true for the higher pressure jobs and it is in this field that economizers are most frequently installed. In the low pressure range, i.e., say 500 lb. and below, the boiler-air heater combination predominates.

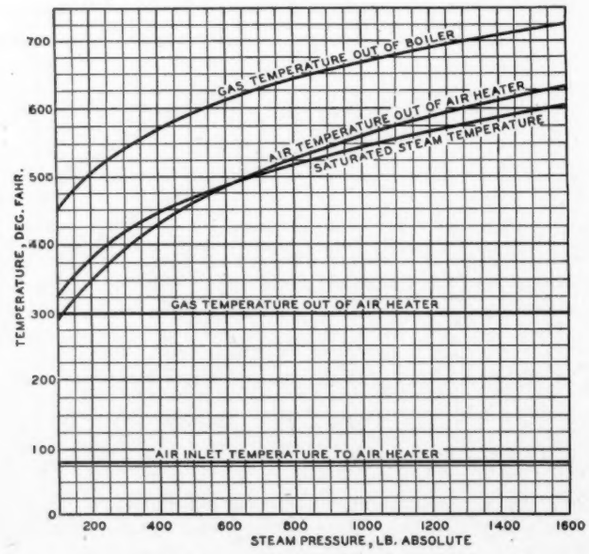

GAS TEMPERATURE OUT OF BOILER
AIR TEMPERATURE OUT OF AIR HEATER
SATURATED STEAM TEMPERATURE
GAS TEMPERATURE OUT OF AIR HEATER
AIR INLET TEMPERATURE TO AIR HEATER
TEMPERATURE, DEG. FAHR.
STEAM PRESSURE, LB. ABSOLUTE

**Fig. 3—Effect of adding an air heater to boiler of Fig. 1.**

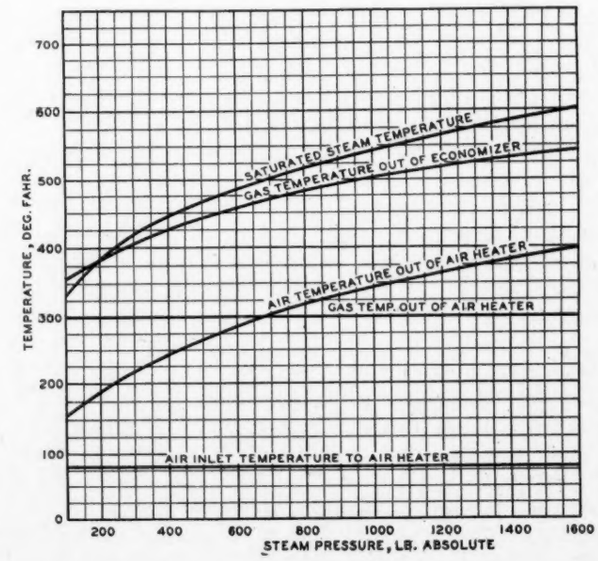

SATURATED STEAM TEMPERATURE
GAS TEMPERATURE OUT OF ECONOMIZER
AIR TEMPERATURE OUT OF AIR HEATER
GAS TEMP. OUT OF AIR HEATER
AIR INLET TEMPERATURE TO AIR HEATER
TEMPERATURE, DEG. FAHR.
STEAM PRESSURE, LB. ABSOLUTE

**Fig. 4—Effect of adding an air heater to boiler and economizer combination of Fig. 2.**

High pressure, high superheat, steel-tube economizers, water-cooled furnaces, air preheaters and feedwater heated to high temperature by extracted steam from the main turbines have all contributed to the wide range of variation in unit arrangement and in distribution of heating surface encountered in present day practice. These developments have followed one another so rapidly that their assimilation into logical economic standardized units is far from being realized.

Standardization within narrow limits can in all probability never be accomplished. The fact that the boiler, economizer and air preheater may be treated as independent units which can be readily assembled into a combination unit by the introduction of suitable connecting duct work permits great flexibility in general arrangement. Arrangements may consequently be readily adapted to restrictions imposed by existing building or site conditions or to conform to the fads, fancies and reasoned requirements of the engineer in charge of design. In the presence of such inherent flexibility an arbitrary stand in favor of a standardized arrangement is not commercially practical in an acutely competitive world.

Economic factors, i.e., cost and kind of fuel, load factor and construction costs, vary between wide limits. In each specific case these factors fix the limit beyond which the cost of additional increments of heat absorbing surface are not compensated by the corresponding added increment of fuel saving.

With multi-drum bent-tube boilers it is practically always economically desirable to put in the maximum possible amount of boiler tube surface as fixed by specific drum dimensions. The drum length will be fixed by furnace width required. The steam drum diameters will be fixed by considerations of water storage and steam liberating space. Only the bottom drum will vary with the number of tubes installed. The cost of tube surface over and above the fixed cost of the drums becomes a matter of the cost of the tubes themselves plus a labor charge. Tubes are comparatively cheap. It will be apparent therefore that having provided drum facilities for installing tubes these facilities should be used to the limit.

With cross-drum sectional-header-type boilers each tube added requires about 6 in. of header at each end. The cost of the headers will approach and in many cases exceed the cost of the tubes. Added increments of tube surface may therefore not prove to be the cheapest form of heat absorbing medium.

The alternative to tube surface in the boiler is economizer or air preheating surface. The initial step in the addition of an economizer is expensive as it involves inlet and outlet headers, inter-connecting piping and duct work, induced draft fans, supporting structure, etc. Having taken the initial step, however, additional increments of surface result in only small increments of increased cost in the aforementioned incidental items. These increments may be more or less expensive than equal increments of boiler surface. As a general statement they will be more expensive than tube surface in a bent tube boiler. The cost of such increments in the economizer and equal increments in a sectional header boiler will vary from slightly less to appreciably more depending upon details of construction. The economic preference however is substantially determined by a comparison of:

$$\frac{\text{tem. dif. bet. gas and water} \times \text{rate of heat trans.}}{\text{cost per sq. ft. of surface}}$$

In this formula the economizer will invariably have the advantage in temperature difference and it may practically always be arranged to secure a higher mass flow of gases than is convenient in the boiler and hence will have the advantage of a higher heat transfer rate. A premium in cost per square foot of added increments of surface in the economizer with a corresponding omission of surface in the sectional-header boiler may often be carried a good way with economy. Such a substitution is seldom if ever economically possible with a bent tube boiler within the limit of boiler tube surface which may be installed without increasing drum dimensions.

Practice up to a few years ago, and particularly in the day of the vertical cast-iron-tube economizer, limited the upper temperature to which the water might be raised in an economizer to a value of about 50 fahr. below the boiling point corresponding to boiler pressure. This 50 deg. was a safety margin to avoid the possibility of steam formation in the economizer under operating conditions. When the limiting temperature of feedwater as heated by exhaust steam from auxiliaries was 212 fahr., the range of temperature through which the water could be heated by an economizer gave plenty of latitude for its application. With the advent of feedwater heated to 350 fahr. and higher by steam extracted from the main turbine, the retention of the 50 deg. fahr. margin left only a very small range of temperature for the economizer to work on. The increase in steam pressure and the consequent increase in boiling temperature relieved this condition somewhat but not enough in many cases to make more than a small economizer practical. With modern design of steel-tube economizers and proper piping connection between the economizer and boiler drum, however, no fear of damage in the event of steam formation in the economizer need be entertained, and the restriction on their use as imposed by the 50 deg. margin, formerly considered necessary, has been removed. Some installations have in fact been made with the economizer deliberately proportioned to heat the water up to boiling and to evaporate as much as 10 per cent of it before passing the mixture to the boiler. It may be said that as at present designed no restriction is imposed on the economic limit to which economizer surface may be substituted for boiler heating surface by the range of temperature through which the water may be heated by its use. In making this statement, it should be added that, if possible or probable generation of steam in the economizer is anticipated, the arrangement should be such that water flow

will be upward through the economizer bank. With downward flow, pockets of accumulated steam would appear to be a possibility. Though damage resulting from such an occurence is not a proved fact, it is thought that it might prove troublesome.

Any general statement or series of statements to cover all cases of when and when not to include economizers is impossible. It is however possible to generalize to the extent of saying:

1. If an efficiency is being aimed at which can be secured with a flue gas temperature of 125 fahr. or more above the temperature corresponding to boiler pressure, an economizer with either a bent tube or a sectional header type of boiler will not pay.

2. If an economizer is to be justified at all, sufficient surface to reduce the temperature of the flue gas to a point substantially below that which is easily possible with boiler heating surface will be found profitable. The exact value will of course be strongly influenced by the temperature of the feedwater inlet.

Statements 1 and 2 imply that no combination of boiler and economizer can be justified for a considerable range of flue gas temperature lying immediately below that temperature which can be secured by a boiler alone. This is actually the case and is a fact which simplifies the decision as to whether or not economizers can be justified in any particular case. Cost estimates with and without economizers based on the differential temperature indicated in Figs. 1 and 2 considered in relation to fuel saving will nearly always give a positive answer for or against economizers.

Having decided on economizers, the problem of to just what extent boiler heating surface may be replaced by economizer surface should in the first instance be put up to the manufacturers of the combined unit as they alone are in possession of the necessary detailed cost and performance data on which to base a solution.

What has been said with reference to boiler and economizer combinations can very nearly be repeated with respect to combination of boilers and air heaters. The combination cannot be justified for an efficiency which can be obtained with the boiler alone. To justify the incidential expense of cold and hot air ducts, induced and forced draft fans, gas ducts and supporting structures demand that if an air heater is to be put in at all it must be made to work and add a substantial increment of efficiency above that obtainable with the boiler alone. As indicated in Fig. 3 it is possible under all conditions to reduce the final temperature of flue gas to 300 fahr. by the application of an air heater to an efficient boiler. The increment of efficiency which this adds may be noted in Fig. 1.

For other than exceptional cases an air preheater in combination with a boiler unit, for moderate and low pressure jobs is a more economical proposition than a boiler and economizer. When air temperature must be limited to conform to stoker requirements then an economizer must be added to obtain the maximum efficiency. For extremely high pressures a combination of boiler, economizer and air heater may work out to better advantage than a boiler and air heater only. In any case it will be necessary to have an air heater if the maximum efficiency is desired. This will be apparent upon referring to Figs. 2 and 4.

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## Robert E. Doherty Appointed Dean of the School of Engineering at Yale

President James R. Angell, of Yale University, has appointed Robert E. Doherty, professor of electrical engineering and at one time a working associate of the late Dr. Charles P. Steinmetz, as dean of the newly organized school of Engineering at Yale. Thereby Professor Doherty will be enabled to carry forward still more effectively a double Steinmetz ideal in which he also has been personally ardent—the ideal of electrical development through well trained engineers and the ideal of education as a social force in the American nation.

Originally it was Professor Doherty's skill as a mathematician which, in 1920, attracted Steinmetz's attention to him. Steinmetz, himself one of the great mathematicians of his time, and possibly the greatest contemporary mathematician in electrical practice, found Doherty's talents in that direction of great assistance to him. The two spent three mutually profitable years upon engineering problems then recurring in the electrical work of the General Electric Company, and they remained colleagues until Steinmetz's untimely death in 1923.

It was Doherty's keen interest in education which made him more than ever congenial to Steinmetz. They found themselves in general agreement as to the desirable attitude of young men toward education and particularly that of prospective engineers. Steinmetz for years warmly advocated a broad educational background for students who planned to become electrical engineers. He had urged that they should not by any means neglect the classical branches of learning.

After Steinmetz's death, Professor Doherty organized and had charge of the General Electric Company's advanced course in engineering, which made effective use of the many educational opportunities of the company's technical organization and facilities. The course lasted three years, being open to a selected small group of college graduates. It specialized in design engineering, and almost immediately came to be recognized as a distinctive contribution to advanced technical education.

Professor Doherty served on the general education committee of the General Electric Company, was appointed in 1919 a member, and later chairman, of the educational committee of the American Institute of Electrical Engineers, and was contact man for college professors who did summer work with General Electric. He was appointed professor of electrical engineering, at Yale University in April, 1931.

# Performance of Modern Steam Generating Units*

By C. F. HIRSHFELD[1] and G. U. MORAN[2]

**This paper* is the final report on a study made of the performance of 250 large steam boilers over a period of three years. The results of the first year's study were reported at the 1929 Annual Meeting of the A.S.M.E., and a summary of the full three-year period was presented at the 1931 Annual Meeting. The study was requested by the Central Station Power Committee of the Power Division. The primary object was to study boiler outages and their causes and the effect of such factors as severity of use, design, fuels, and methods of firing on boiler reliability, in the hope that a yardstick might be obtained by which the individual operator could measure the performance of his own units and predict the probable availability of new designs. In the complete paper the data obtained from each unit are presented, together with some comparisons of types and classes of unit. There also is a discussion of primary causes of boiler shutdown, which has not appeared in either of the previous papers.**

STEAM-GENERATING EQUIPMENT has received its share of attention in technical literature and discussion, with respect to most of the factors affecting its design and operation. The quite considerable increase in thermal economy, which has been attained during the past two decades, has been widely discussed. The former "boiler" has evolved into that complicated structure we now know as the steam-generating unit, but the development was by no means made blindly. The effect on thermal efficiency of each addition to and refinement of the "boiler" has been determined to such a degree that the designer may predict with confidence the thermal performance of his creation. This knowledge has made it possible to weigh investment cost against probable savings and to define limits beyond which an increase in efficiency would be overbalanced by a disproportionately large increase in initial cost.

But low investment is not of itself a complete criterion on the dollar side of the picture. A large investment which can be used for, say, 80 per cent of each complete year of the life of a plant may represent a better economic solution than a smaller investment made to accomplish the same result, but usable only during, say, 50 per cent of the entire year. In other words, the extent to which equipment can be kept in as continuous service as existing conditions indicate to be ideally desirable is also an important measure.

Thermal efficiency is comparatively easy of proof. Investment made is merely a question of fact. The performance factor, however, is a question of experience, and any one individual's intimate experience must necessarily be limited to a comparatively small number of installations. It results that while there is available a wealth of information concerning thermal efficiences and first costs of steam-generating plants, there is very little information about the extent to which various features of design influence the ability of those plants to produce when and as required.

This fact was appreciated by the Central Stations Committee of the Power Division, A. S. M. E., when it requested the authors to make this investigation and to provide if possible a yardstick of normal values by which the individual operator might determine whether his performance was good, bad, or normal.

The study was started in July, 1928, with the collection of daily operating data from 186 boiler units located in 50 plants well scattered throughout the United States. The analysis of one year's records, which was presented as a paper before the Power Division at the Annual Meeting, December, 1929, showed that, if significant results were to be obtained, the study should be continued over a longer period and a larger number of units should be included. The present paper therefore represents an investigation of 250 units in 61 stations, covering the three-year period between July 1, 1928, and July 1, 1931. A progress report was made at the Annual Meeting in December, 1931. It contained a general summary of the data at hand, but due to lack of sufficient time for preparation, the more detailed report was postponed and constitutes this, the final paper.

The procedure followed in obtaining the data has been set forth in the 1929 paper, together with

* Abstract of paper to be presented at the annual meeting of the A.S.M.E., New York, Dec. 5 to 9, 1932.

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[2] Research Department, Detroit Edison Company.

TABLE 4 SUMMARY OF OPERATING RECORDS

| Period covered in years | Number of units in group | Pressure class, lb. per sq in. gage | Percentage of total period: Steaming | Banked | Reserve | Crippled | Use factor | Availability factors: Individual High | Individual Low | Group | Group performances: Percentage of total period: Steaming | Banked | Reserve | Crippled | Use factor | Availability factor |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Stoker-Fired Units* | | | | | | | | | | | | | | | | |
| 3.0 | 14 | 500–700 | 57.3 | 18.1 | 5.9 | 18.7 | 0.754 | 0.846 | 0.774 | 0.813 | | | | | | |
| 2.0 | 10 | 500–700 | 74.5 | 3.8 | 5.5 | 16.2 | 0.783 | 0.852 | 0.802 | 0.838 | 62.8 | 13.5 | 5.8 | 17.9 | 0.763 | 0.821 |
| 3.0 | 1 | 400–499 | 69.3 | 6.9 | 2.6 | 21.2 | 0.762 | 0.788 | 0.788 | 0.788 | | | | | | |
| 2.5 | 3 | 400–499 | 60.4 | 5.0 | 0.6 | 34.0 | 0.654 | 0.713 | 0.622 | 0.660 | | | | | | |
| 2.0 | 4 | 400–499 | 48.4 | 25.3 | 2.2 | 24.1 | 0.737 | 0.788 | 0.730 | 0.759 | | | | | | |
| 1.5 | 4 | 400–499 | 83.0 | 7.0 | 0.6 | 9.4(?) | 0.900 | 0.913 | 0.898 | 0.906 | 63.1 | 12.4 | 1.3 | 23.2 | 0.755 | 0.768 |
| 3.0 | 24 | 300–399 | 70.6 | 9.0 | 4.9 | 15.5 | 0.796 | 0.936 | 0.708 | 0.845 | | | | | | |
| 2.0 | 13 | 300–399 | 58.7 | 9.3 | 15.1 | 16.9 | 0.680 | 0.964 | 0.707 | 0.831 | | | | | | |
| 1.5 | 4 | 300–399 | 72.5 | 8.0 | 2.1 | 17.4 | 0.805 | 0.904 | 0.760 | 0.826 | | | | | | |
| 1.0 | 13 | 300–399 | 70.9 | 9.6 | 11.9 | 7.6(?) | 0.805 | 1.000 | 0.933 | 0.924 | 68.0 | 9.1 | 7.8 | 15.1 | 0.771 | 0.849 |
| 3.0 | 12 | 200–299 | 55.8 | 14.8 | 11.5 | 17.9 | 0.706 | 0.936 | 0.705 | 0.821 | | | | | | |
| 2.5 | 3 | 200–299 | 24.8 | 48.8 | 15.1 | 11.3 | 0.736 | 0.899 | 0.875 | 0.887 | | | | | | |
| 2.0 | 6 | 200–299 | 62.6 | 12.8 | 8.4 | 16.2 | 0.754 | 0.905 | 0.761 | 0.838 | | | | | | |
| 1.5 | 4 | 200–299 | 72.8 | 3.2 | 6.3 | 17.7 | 0.760 | 0.922 | 0.660 | 0.823 | | | | | | |
| 1.0 | 7 | 200–299 | 56.7 | 23.5 | 3.2 | 16.6 | 0.820 | 0.980 | 0.650 | 0.834 | 55.2 | 18.0 | 10.0 | 16.8 | 0.732 | 0.832 |
| Performance of stoker-fired class | | | | | | | | | | | 63.2 | 12.6 | 7.3 | 16.9 | 0.758 | 0.831 |
| *Pulverized-Fuel-Fired Units* | | | | | | | | | | | | | | | | |
| 3.0 | 1 | 500–700 | 64.3 | 2.1 | 14.3 | 19.3 | 0.664 | 0.807 | 0.807 | 0.807 | 64.3 | 2.1 | 14.3 | 19.3 | 0.664 | 0.807 |
| 3.0 | 8 | 400–499 | 66.4 | 12.2 | 10.3 | 11.1 | 0.786 | 0.949 | 0.788 | 0.889 | | | | | | |
| 2.0 | 6 | 400–499 | 54.7 | 7.3 | 23.8 | 14.2 | 0.620 | 0.972 | 0.710 | 0.858 | | | | | | |
| 1.0 | 15 | 400–499 | 71.0 | 3.9 | 19.3 | 5.8(?) | 0.749 | 1.000 | 0.732 | 0.942 | 65.8 | 8.0 | 16.5 | 9.7 | 0.738 | 0.903 |
| 3.0 | 12 | 300–399 | 52.1 | 12.7 | 18.2 | 17.0 | 0.648 | 0.954 | 0.664 | 0.830 | | | | | | |
| 2.0 | 8 | 300–399 | 68.0 | 8.6 | 3.4 | 20.0 | 0.766 | 0.843 | 0.738 | 0.800 | | | | | | |
| 1.0 | 19 | 300–399 | 64.5 | 8.5 | 16.3 | 10.7 | 0.730 | 0.954 | 0.711 | 0.893 | 59.0 | 10.6 | 14.4 | 16.0 | 0.696 | 0.840 |
| 3.0 | 2 | 200–299 | 88.9 | 2.9 | 0.1 | 8.1 | 0.918 | 0.925 | 0.914 | 0.919 | | | | | | |
| 2.5 | 2 | 200–299 | 41.6 | 28.4 | 11.4 | 18.6 | 0.700 | 0.825 | 0.807 | 0.814 | | | | | | |
| 2.0 | 3 | 200–299 | 86.0 | 5.5 | .. | 8.5 | 0.915 | 0.939 | 0.884 | 0.915 | | | | | | |
| 1.0 | 6 | 200–299 | 71.0 | 3.5 | 11.3 | 14.2 | 0.745 | 0.905 | 0.602 | 0.858 | 73.2 | 9.3 | 5.4 | 12.0 | 0.825 | 0.879 |
| Performance of pulverized-fuel-fired class | | | | | | | | | | | 63.8 | 9.3 | 13.8 | 13.1 | 0.731 | 0.869 |
| *Oil- and Gas-Fired Units* | | | | | | | | | | | | | | | | |
| 3.0 | 6 | ..... | 54.5 | 26.7 | 11.6 | 7.2 | 0.812 | 0.969 | 0.897 | 0.928 | | | | | | |
| 2.0 | 4 | ..... | 52.8 | 14.7 | 18.9 | 13.6 | 0.675 | 0.908 | 0.779 | 0.864 | | | | | | |
| 1.5 | 3 | ..... | 47.0 | 2.3 | 12.5 | 38.2 | 0.493 | 0.706 | 0.489 | 0.618 | | | | | | |
| 1.0 | 11 | ..... | 71.7 | 5.6 | 8.9 | 13.8 | 0.773 | 0.977 | 0.758 | 0.862 | 57.9 | 16.1 | 12.4 | 13.6 | 0.740 | 0.864 |
| *Combined Fuels* | | | | | | | | | | | | | | | | |
| 3.0 | 3 | ..... | 39.0 | 36.6 | 19.2 | 5.2 | 0.756 | 0.972 | 0.936 | 0.948 | | | | | | |
| 2.5 | 3 | ..... | 86.2 | 3.7 | 0.2 | 9.9 | 0.899 | 0.929 | 0.868 | 0.901 | 60.5 | 21.7 | 10.5 | 7.3 | 0.822 | 0.927 |

TABLE 5 EFFECT OF LENGTH OF STUDY ON RESULTS OBTAINED—PERFORMANCE FIGURES BY CLASSES

| 1929 findings, all boilers: Period covered in years | Number of units in group | Use factor | Availability factors: Individual High | Individual Low | Group | 1931 findings, all boilers: Period covered in years | Number of units in group | Use factor | Availability factors: Individual High | Individual Low | Group | 1931 findings, after elimination of questionable units[a]: Period covered in years | Number of units in group | Use factor | Availability factors: Individual High | Individual Low | Group |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Stoker-Fired Units* | | | | | | | | | | | | | | | | | |
| 1 | 101 | 0.769 | 1.000 | 0.430 | 0.839 | 3 | 122 | 0.758 | 1.000 | 0.622 | 0.831 | 3 | 111 | 0.752 | 0.980 | 0.622 | 0.825 |
| *Pulverized-Fuel-Fired Units* | | | | | | | | | | | | | | | | | |
| 1 | 62 | 0.723 | 0.952 | 0.494 | 0.877 | 3 | 82 | 0.731 | 1.000 | 0.602 | 0.869 | 3 | 73 | 0.730 | 0.972 | 0.602 | 0.855 |
| *Oil- and Gas-Fired Units* | | | | | | | | | | | | | | | | | |
| 1 | 17 | 0.753 | 0.949 | 0.581 | 0.897 | 3 | 24 | 0.740 | 0.977 | 0.489 | 0.864 | 3 | 24 | 0.740 | 0.977 | 0.489 | 0.864 |

[a] Certain numbers given in Table 4 are followed by a question mark. Inspection will show that they represent extraordinarily low values for crippled hours. It is believed that the low values either result from an unintended interpretation of definitions or that the age of the units is not sufficient to have brought about a representative average performance.

TABLE 6 COMPARISON OF AVAILABILITY FACTORS OF PULVERIZED-FUEL-FIRED UNITS OF THE UNIT AND STORAGE TYPES

| Type | Total hours reported | Crippled hours | Crippled hours not directly chargeable | Net crippled hours | Availability factor |
|---|---|---|---|---|---|
| Unit | 234,113 | 36,198 | 25,833 | 10,365 | 0.955 |
| Storage | 828,153 | 112,887 | 78,112 | 34,775 | 0.958 |

TABLE 7 COMPARISON OF AVAILABILITY FACTORS OF STOKER-FIRED UNITS OF THE UNDERFEED AND TRAVELING GRATE TYPES

| Type | Total hours reported | Crippled hours | Crippled hours not directly chargeable | Net crippled hours | Availability factor |
|---|---|---|---|---|---|
| Underfeed | 1,305,217 | 213,404 | 86,152 | 127,252 | 0.903 |
| Traveling grate | 701,940 | 127,701 | 63,603 | 64,098 | 0.909 |

TABLE 8 COMPARISON OF AVAILABILITY FACTORS OF UNITS HAVING AIR PREHEATERS WITH THOSE NOT HAVING AIR PREHEATERS

| | Total hours reported | Crippled hours | Crippled hours not directly chargeable | Net crippled hours | Availability factor |
|---|---|---|---|---|---|
| *Stoker-Fired Units* | | | | | |
| With preheaters | 676,662 | 134,107 | 20,178 | 113,929 | 0.832 |
| Without preheaters | 984,016 | 154,578 | 51,163 | 103,424 | 0.895 |
| *Pulverized-Fuel-Fired Units* | | | | | |
| With preheaters | 671,443 | 117,567 | 62,688 | 54,879 | 0.918 |
| Without preheaters | 351,180 | 29,063 | 12,659 | 16,404 | 0.953 |
| *Oil- and Gas-Fired Units* | | | | | |
| With preheaters | 168,816 | 18,749 | 7,245 | 11,504 | 0.932 |
| Without preheaters | 141,071 | 10,802 | 3,780 | 7,022 | 0.950 |

definitions used. To conserve space the method will not be repeated here in detail. Suffice it to say that the data were collected by means of printed log sheets which were filled out by the operators themselves and analyzed by a single group of men in the office of the authors. Particular attention was given to crippled periods or outages and their extent, cause, and frequency, with enough other information to give the authors some idea of the operating and load conditions to which the individual units were subjected Design and descriptive data were also obtained for each unit studied.

Tables 1, 2 and 3 (*not included in this abstract*), give these data for each unit separately. For convenience they are grouped according to method of firing and further subdivided into steam-pressure classes. They are ordered according to average rate of driving, expressed as kb (1000 B.t.u.) output of the entire unit per square foot of saturated heating surface. Each unit has a designation consisting of a letter or letters and a number. The letter classifies the unit as to method of firing or the type of fuel burned, as: S, stoker-fired; P, pulverized-coal-fired; OG, oil- and gas-fired. A fourth group consisting of units using coal and either gas or oil is designated by the letter M. The numbers indicate the position in the group in which the unit falls. In the case of reheat boilers, the letter R follows the firing-method designation and precedes the number. Each individual unit carries the same designation in every table in which it may appear.

At this point it might be well to insert a note of caution to the reader so that he may not be misled by mere figures. As in the first year of the study, some difficulty was encountered in apportioning the reported crippled hours among the various causes. The operators were requested to give the primary cause of outage in each case, but many occasions arose in which more than one part of the unit was worked on at one time. For instance, the boiler might be shut down and crippled for repairs to the furnace, but the operators might very naturally take advantage of the opportunity to make extensive repairs to the boiler or stoker. These latter might not be in any way urgent, but would certainly tend to defer or even avoid future shutdown for such work. Also it is the practice of many operators to schedule repair work at definite intervals. This permits the maintenance crew to do the most work in the least elapsed time by working on several parts of the unit simultaneously. In such instances the operators were requested to give more detailed information, especially when the original log sheets showed an appreciable divergence from the average. By this means the authors have been able to correct much of the misleading data. Table 4 is a summary of the operating records, with the units grouped according to steam pressures and firing methods and further subdivided according to the length of time represented by the operating records received. The figures under the heading "Group performances" are averages weighted according to the number of boiler-hours involved in each case. The method of weighing was described in detail in the progress report, under the same title as this paper, presented before the Power Division at the 1931 Annual Meeting. The figures for class performances were computed in a similar manner.

Table 5 is reprinted from the 1931 paper where it appeared as Fig. 2. It compares the results of the three-year study with those obtained in the first year. The 1931 paper contained a detailed discussion of the comparison, which need not be repeated here.

Further subdivision of the pulverized-coal-fired and stoker-fired groups has been made. Table 6 compares the unit and storage types of pulverized-coal firing. The availability factors first given are those taken directly from Table 2 and weighted as in Table 4. The second pair were obtained by eliminating those outages which are not affected by the method of firing and retaining only those which bear directly. At first glance it would seem that there is very little difference between the two types, but on closer inspection of the second comparison the storage type has the advantage. There is too much difference, however, in the number of boiler-hours involved to justify placing too great weight on this result. Also, the difference between high and low limits in each case is far greater than the difference between the averages.

Table 7 shows underfeed and traveling-grate stokers treated in like manner. Here again the difference may be within the accuracy of the data.

The effect of air preheat on unit availability is another much-discussed point. This is shown for the units studied in Table 8. The decrease in availability due to preheat is still marked, being from 0.018 to 0.063, but not as great as that shown by the 1929 results, when the decrease was in all classes greater than 0.05. This would seem to indicate that the use of preheat is now better understood or that the degree of preheat has been reduced. At any rate the results are so consistent that it is reasonable to assume that they represent fact.

In order to show the degree of use of the various classes of steam-generating units, load-duration curves were constructed for each class. They are shown in Fig. 1. The percentage of

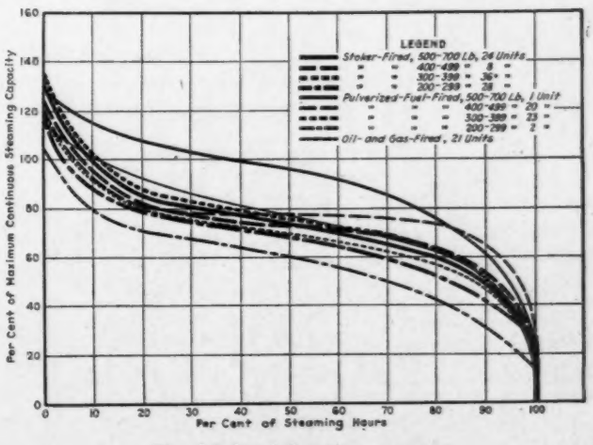


**Fig. 1—Load-duration curves.**

maximum continuous steaming capacity, as given by the operators, is plotted against the percentage of steaming time. With the exception of a group of two boilers below the average and a single unit above, the main body lies in a narrow band across the face of the chart, showing that the boilers in general were operated at approximately equal rates with respect to the standards set up for them by the designers. This in a sense bears out the conclusion arrived at after the first year's study. It was noted at that time that the apparent severity of use based on heat output per unit of heating surface had no appreciable effect on availability. Reference is made to Figs. 9 and 10 of the 1929 report. Fig. 1 of this paper indicates that boilers showing the higher unit rates of output were purposely designed for such conditions and apparently have fulfilled the intents of their designers.

The discussion up to this point has dealt with boiler outages grouped under a few necessarily large heads. Realizing that further study of these individual heads would be of considerable interest, the authors choose the three largest items charged to each unit—for instance, the stoker, furnace, and boiler or the pulverizing equipment, boiler, and economizer, as the case might be—and requested that the operators make a brief statement as to outstanding troubles and primary causes.

Table 9 is an attempt to summarize the replies and to put them in such form that comparisons may be made between pressure and fuel classes. Some of the finer detail has of necessity been omitted, as it would serve only to confuse, without bringing to light anything of general applicability.

In every instance there were several units for which the outages were classed by the operators as normal or expectable. This was particularly true of the older, well-tried boilers. These are not included in the table for obvious reason. The causes listed, therefore, may be considered as the result of experimentation with new ideas, contingencies, inadequate or faulty design, peculiar local conditions of fuel and operating methods, or a combination of several or all of these factors.

The three or four largest items of outage are presented for each class of unit and are arranged in order of magnitude. They appear in the table in the column headed "Part of unit crippled." Under the next column, headed "Reason for outage," are listed the causes of shutdown as furnished by the operators.

No attempt was made to list them in order of importance or magnitude as the individual lengths of time are not available. They are considerably abbreviated, but every effort was made to preserve the intended meaning of the operators.

In examining Table 9 it will be noticed that, with one exception, the furnace, stoker, boiler, and superheater were greatest offenders in the stoker-fired classes. The exception was the large outage due to cleaning dust-clogged air preheaters and excess slag accumulations from the boiler tubes. This latter probably would have resulted in crippling the boiler proper if left long enough, so it might with reason be termed an incipient boiler outage, if not an actual one.

The stokers seem to have had their greatest difficulties with preheated air and the wrong type of coal. In each pressure class one of the largest stoker outages was due to burned parts, caused by preheated air in the two higher pressure classes, and low-ash, low-volatile coal in the 200-299-lb. class. No details were given for the 300-399-lb. class. As the 500-700-lb. class units are fired with traveling grates and the 400-499-lb. class use underfeed stokers, no evidence is given as to the relative ability of the two types to resist preheat.

Plain refractory walls were the cause of considerable crippled time in all classes but that of 400-499-lb. In this class 8 of the 12 boilers have furnaces which are almost entirely water-cooled. In many instances slag accumulation and erosion hastened the failure of the plain walls, which was to be expected in view of the large stoker outages due to coal conditions.

Tube replacements and valve repair constituted the greater part of the boiler and superheater outage, with three instances in the 300-399-lb. class of

TABLE 9 MAJOR OUTAGES

| Pressure class | Stoker-fired units: Order of magnitude | Part of unit crippled | Reason for outage | Pulverized-fuel-fired units: Order of magnitude | Part of unit crippled | Reason for outage | Oil- and gas-fired units: Order of magnitude | Part of unit crippled | Reason for outage |
|---|---|---|---|---|---|---|---|---|---|
| 500–700 lb... | 1 | Furnace | (a) Plain refractory walls<br>(b) Low fusion coal | 1 | Furnace | (a) Arch failures<br>(b) Burned secondary-air-inlet parts | | | |
| | 2 | Stoker | (a) Burned parts due to preheated air<br>(b) Mechanical drive | 2 | Economizer | (a) Some tubes rerolled twice each month | | | |
| | 3 | Boiler and superheater | (a) Overloaded soot blowers due to coal used<br>(b) Replacement of tubes | | | | | | |
| 400–499 lb... | 1 | Stoker | (a) Burned parts due to preheated air<br>(b) High ratings<br>(c) Removal of secondary rams and links on link grates | 1 | Boiler and superheater | (a) Rearrangement of superheater supports<br>(b) Failure of superheater tubes | | | |
| | 2 | Boiler and superheater | (a) Renewal of valve seats and disks | 2 | Furnace | (a) Rearrangement of front walls to secure more suitable air distribution | | | |
| | 3 | Cleaning gas side of heating surface | (a) Plugged air preheaters<br>(b) Excess slag accumulation | | | | | | |
| 300–399 lb... | 1 | Stoker | (a) Burned stoker parts<br>(b) Mechanical drive | 1 | Furnace | (a) Failure of water-cooled steel blocks<br>(b) Rebuilding refractory walls | 1 | Boiler and superheater | (a) Warping of support members by leaking gases<br>(b) Leaking stop valves |
| | 2 | Boiler and superheater | (a) Tube replacement<br>(b) Valve repair<br>(c) Failure of radiant superheater elements<br>(d) Slag deposits | 2 | Boiler and superheater | (a) Replacement of radiant-superheater elements<br>(b) Superheater tubes cut by steam from misaligned soot blower | 2 | Furnace | (a) Chipping of burner wall brick |
| | 3 | Furnace | (a) Slag deposits<br>(b) Rebuilding refractory walls | 3 | Pulverising equipment | (a) Renewal of mill hammers, liners, grinding balls | | | |
| | | | | 4 | Draft equipment | (a) Vibration of induced-draft fans<br>(b) Erosion of fan blades by fly ash<br>(c) Failure of fan-shaft assemblies at preheaters | | | |
| 200–299 lb... | 1 | Boiler and superheater | (a) Replacement of tubes | 1 | Boiler and superheater | (a) Tubes cut by steam from misaligned soot blowers<br>(b) Overheated superheater tubes | | | |
| | 2 | Furnace | (a) Rebuilding refractory walls | | | | | | |
| | 3 | Stoker | (a) Burned parts due to low-ash, low-volatile coal<br>(b) Mechanical drive | | | | | | |

warped elements in radiant superheaters. Coal conditions again appear to have considerable effect on performance, as many operators reported excessive slag deposits on tubes and overworked or ineffective soot blowers in cases where the amount of ash entrained with the furnace gases was abnormally high.

A somewhat different picture is presented in the pulverized-fuel column. In only one pressure class does the fuel-burning equipment, i.e., the burners and pulverizing and conveying equipment, take a position as one of the three largest sources of outage. In the 300-399-lb. class considerable time was spent in replacing mill hammers, liners, and grinding balls, but in all other instances the operators considered such outages as normal.

Furnace troubles were much the same as with the stoker-fired units where plain refractory walls were concerned. In the cooled or protected walls considerable outage was due to the burning of the wall surface. In the case of one station the bare steel blocks were removed after unsuccessful attempts to keep them in service, and cast-iron blocks were substituted for them. The results had been satisfactory at the time of the last report. In another instance the bare secondary air-port blocks burned badly, necessitating frequent replacement.

Two stations experienced difficulty in maintaining correct alignment of soot-blower elements due to warping. The result was the cutting of boiler and superheater tubes to such an extent that tube replacements were abnormal.

Only one station reported outages other than normal in the oil- and gas-fired group. Even these were of a comparatively minor character, and all repairs were made during scheduled overhaul periods.

### *Conclusions*

In general, the results of the three-year study bear out the relationships indicated by the 1929 report, the differences being only those of degree. All groups and classes have apparently dropped slightly in availability, probably because of added outages, which generally are not annual occurrences. The question of age might arise, as the greater number of units included in the study were two years older at the end of the three-year period than they were in 1929, but it is not believed to have had much influence in this case because of the fact that boilers of radically different ages were considered in both the short-time and long-time studies.

There still seems to be no appreciable difference in reliability between pulverized-fuel firing and stoker firing. The small margin in favor of the former method is very small when compared with the range between high and low individual values in both groups. While it is true that outages due to the stoker proper are somewhat greater than those chargeable to the pulverizing and burning equipment alone, it must be kept in mind that there are many other factors of intangible character which might easily have a more than balancing effect. Such factors are the amount of stoker and pulverizer repair work done as scheduled overhaul, and local fuel and load-schedule conditions. Also, as pointed out in both previous papers, any hard and fast conclusions must be avoided in a study of this kind because of the many variables involved and the differences of opinion and maintenance standards which are inevitable in a widely scattered group of some sixty-odd operators.

Probably one of the most illuminating parts of this final study is the material contained in Table 9. The influence of local conditions is brought out very sharply. Many units are afflicted with a very poor grade of coal, while others suffer from the use of fuel of too high a grade. Experiments in design are being conducted in many stations. Preheated air is becoming more generally understood.

The modern steam-generating unit seems to have been in a state of rapid and constant development at the time when these data were collected. The authors have reason to believe that this is still the case. Such development inevitably results in abnormal operating and maintenance conditions, which are reflected in the data collected. Suffice it to say that even in this transitory stage, modern steam-generating equipment may be relied on for use from 82 to 86 per cent of the time. There is every indication that this state of affairs will improve somewhat in the future, but until changes in design have become less radical and operating methods more standardized, many abnormal conditions will arise which will tend to confuse and distort the impressions of the investigator and append the question mark to many of his conclusions. For this reason the authors are terminating their study with this paper, believing that a continuation at this time would not be productive of any appreciable increase in the knowledge of the art.

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**Walter F. Perkins,** who has been manager of the Harrison, New Jersey, Works of the Worthington Pump and Machinery Corporation since 1927, has resigned to become vice president and general manager of The Bartlett Hayward Company, Baltimore, Md., where he will assume his new duties December 1st. From 1914 to 1927 Mr. Perkins was associated with The Bartlett Hayward Company and held the position of works manager when he resigned.

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**The Link-Belt Company,** Chicago, announces the recent appointment of George M. Sharer as sales manager of its Eastern division, with headquarters in Philadelphia. In this capacity he has direct supervision of sales of all of the company's offices in the Atlantic Coast States. Mr. Sharer is a mechanical engineer of broad experience, and has been associated with Link-Belt in Philadelphia in various capacities for the past 32 years.

Fig. 1—Gas scrubbers for boilers No. 2 and 4, Kneeland Street Station.

# A New Gas Scrubber

By G. C. DERRY Manager,
Power Apparatus Dept.
B. F. Sturtevant Company

**Prevention of flue dust emission from stacks is one of the most important problems in this field. Much progress has been made in recent years, and many of the most serious difficulties have been overcome. This article reviews the problem and tells of the development and successful application of a new type of gas scrubber which has been in operation for some time past at the Kneeland Street Station of the Edison Electric Illuminating Company of Boston.**

MODERN power stations, particularly of the public utility companies, have been developed into plants for burning coal and turning it into electrical energy at very high efficiencies. This development was an economic necessity as the coal bill of the public utility is a large proportion of its operating expense. This fact has justified the expenditure of large sums which have been devoted to the development of equipment and methods for improving the efficiency of coal utilization. Each B.t.u. has been chased down to its lair and a satisfactory explanation sought as to why it did not do its part in the process of being converted into useful energy.

Naturally, the waste products going up the stack have received much consideration in this development, and for the purpose of this article these waste products will be confined to smoke and flue dust. Modern plants discharge very little smoke due to the fuel being burned by proper equipment in well designed furnaces with the proper control of the process of combustion. In spite of this, however, solid matter is entrained by the gas and discharged from the stacks even in the most carefully designed and operated plants.

### *Smoke and Flue Dust*

We should distinguish between the two types of solid matter actually discharged to the air—the smoke and the flue dust. Smoke may be defined as extremely minute particles varying in diameter between one one-thousandth and one-tenth of a micron. (A micron is the one-thousandth part of a millimeter or, the twenty-five thousand four hundredth part of an inch.) This is a dimension not easy to visualize particularly when we realize that a human hair is about 30 microns in diameter. Flue dust consists mainly of particles of ash varying from ¼ micron to 1/16 in. in dia. Flue dust is entrained in the gases of combustion by their velocity and its presence seems almost unavoidable to a greater or lesser degree.

### *Objectional Features of Flue Dust*

Industrial and public utility operators have two objects in view when considering apparatus for the removal of flue dust. The first is unselfish in their desire to protect their neighbors, who may be customers as well, from the annoyance of having this dust settle down upon them. In the case of the industrial plant, such as a paper mill, a sugar refinery, or a textile plant, this becomes a selfish purpose—to protect their own products. Second is the very vital question of protecting the operating equipment (induced draft fan blades and casing) from the wearing action.

Modern boiler practice demands maximum capacities which involve huge quantities of gas at high velocities to secure the necessary high rates

of heat transfer. The addition of reheat units, economizers, and air heaters, has caused the friction loss to rise from say 3 in. several years ago to 12 or 15 in. now and several designers are considering much higher values. Since the speed of the fan rotor determines its ability to overcome the resistance in the system, which varies as the square of the gas velocity, it is easily seen that tip speeds of the fan rotors have necessarily reached high limits. It is not uncommon to have tip speeds of 20,000 to 25,000 ft. per min. This immediately introduces the problem of erosion not only in the fan housing but also in the rotor, where it is far more serious. Cases have been known where the blades in a rotor have worn through in three weeks. A great deal depends on the design of the rotor, some designs being far more susceptible to erosion than others. Stellite, a tertiary metal consisting of chromium, cobalt and tungsten, has been used at those points where erosion is greatest. However, the use of this metal is confined to the stationary parts or those parts where mild steel is used. Ordinarily the parts of a high speed fan rotor are made of alloy steel carefully heat treated to stand the stresses resulting from such speeds. Since Stellite has to be welded on, it is at once apparent that the heat of welding would destroy the heat treatment and thus weaken the rotor.

Obviously the prevention of flue dust emission from stacks and the erosion of fan rotors with the consequent costs of frequent replacements and loss of service of boiler units are results that would justify a considerable capital expenditure.

It is because of these facts that numerous patents have been taken out on equipment and methods for catching flue dust and much publicity given to the subject. The older art shows many interesting schemes but they have not always been based on scientific knowledge nor have they been carefully worked out in laboratories or in actual use.

The developments of recent years, particularly the trend toward high-capacity plants, have stimulated efforts in this field. These efforts are beginning to bear fruit as evidenced by the designs now on the market. These designs can be broadly classified as electro-static precipitators, dry collectors and wet collectors.

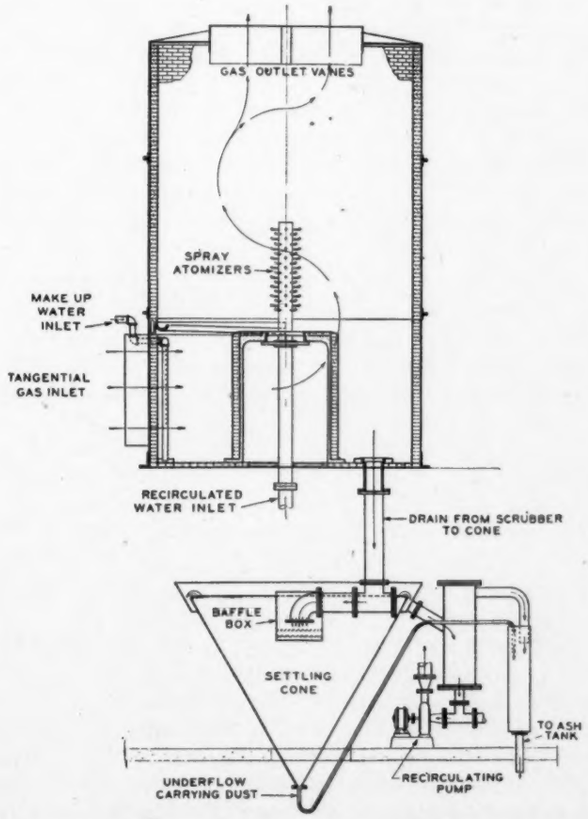


**Fig. 2—Sectional elevation of gas scrubber and settling cone, Kneeland Street Station.**

### *Wet Collectors*

The wet process with its various inherent advantages naturally attracted the attention of designers. Many schemes were tried out and much money expended by public utilities as well as manufacturers in the attempt to solve the problems which naturally developed in this class of equipment. The fact that gas washing removes some of the sulphur oxides immediately places it in a desirable position, but this fact also adds to the difficulties of construction since the wash water becomes acid and vigorously attacks the materials of which the washer is made. In addition, the flue dust is highly abrasive and constantly exposes new surfaces of metals to a fresh attack by the acids. Another decided handicap was the necessity of providing fresh water in large amounts to wash the gas, as it was thought that recirculated water could not be used owing to the increased acid content. The advantages of the wet type and the fact that this type had a high degree of efficiency were granted without question. Nevertheless, the disadvantages mentioned kept it from coming into general use for many years. Within the past two years, however, a new type of collector has been developed and successfully applied in a large utility plant. This installation and the development which led up to it will now be described.

### *Kneeland Street Installation*

The Edison Electric Illuminating Company of Boston made a thorough study of all known types when they designed their Kneeland Street Station. They were faced with the problem of operating boilers of large capacity with powdered coal in the middle of a congested area and the necessity of complete catching of the flue dust. Their attention was attracted to a gas scrubber which had been tried out as an air scrubber for catching very fine dust. It was known as the Pease-Anthony Gas Scrubber and is now manufactured by the B. F. Sturtevant Company of Hyde Park, Boston, Massachusetts. Under the supervision of I. E. Moultrop, Chief Engineer and Superintendent of the Construction Bureau, George Seabury, Superintendent, Station Engineering Department, and M.

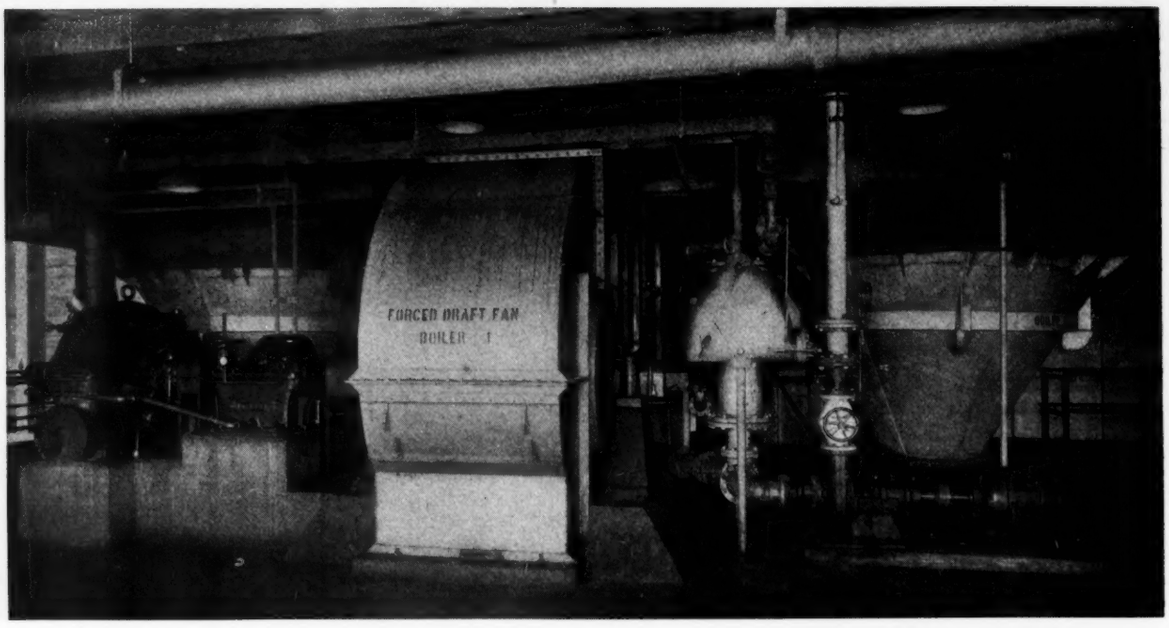


**Fig. 3—Forced draft fan, settling cones and recirculating pump for gas scrubber at Kneeland Street Station.**

D. Engle, Assistant to Superintendent, Station Engineering Department, in collaboration with the engineers of A. D. Little, Inc., on the chemical end of the problem, engineers of the Pease-Anthony Equipment Company, and with the Research Engineers of the B. F. Sturtevant Company, a model scrubber 4 ft. 0 in. in dia. by 8 ft. 0 in. high was built and tested on flue gas from the stoker-fired boilers at the Edison Company's Edgar Plant during the latter part of 1929. The results were so satisfactory that they led to the development of an improved type of gas scrubber which the Edison Company installed in connection with its pulverized fuel fired boilers of 250,000 lb. of steam per hr. capacity, at Kneeland Street, Boston.

This gas scrubber is shown in Fig. 2. The hot dust-laden products of combustion pass through the boiler into the gas scrubber through a tangential gas inlet, at the bottom. The scrubber part consists of a cylindrical tank lined with an erosion and corrosion resisting tile, specially used for this purpose. An axial manifold is equipped with a large number of spray nozzles made of erosion and corrosion resisting material. The gases are caused to pass through the spray zone in a spiral and many of the dust particles meet water droplets while others are driven by centrifugal force to the wet wall of the interior of the scrubber where they are caught and washed down to the bottom of the scrubber. From this point, the water with the dust in suspension passes to a settling device, Fig. 3, where substantially all the dust is concentrated into a small part of the water and withdrawn. Perhaps the most important part of the development is the ability to recirculate the bulk of the water, together with that amount of make-up necessary to supply that lost by evaporation in the scrubbers and withdrawal with the dust in the cones. The concentrated slurry of dust and water is further de-watered, and hauled away from the plant by motor truck. Tests on the scrubber, interpreted with due regard to present methods of measurement of dust content, indicate an annual dust removal efficiency of approximately 95 per cent.

The intimate contact between the hot gases and wash water in the scrubber results in the evaporation of water by the heat of the gases, with a consequent reduction in their temperature. On cold days the water vapor, as it leaves the tops of the stack, condenses into a mist or fog, giving the appearance of steam that soon evaporates and disappears. No trace of condensed moisture has fallen around the plant or onto surrounding buildings even on the quietest or coldest days. The light feathery cloud disappears quickly a short distance from the stack.

The intensity of the wet scrubbing appears to be effective in removing a large portion of the corrosive sulphuric acid resulting from certain sulphur compounds in the gases of combustion. The less corrosive sulphur dioxide gas is taken up much less readily in the scrubber water spray and is discharged into, and diluted by, the atmosphere. It is believed that the efficiency of sulphur or other noxious gas removal can be greatly increased by the use of suitable chemicals and this phase of the work is being actively studied.

In the course of the development of the apparatus the same difficulties were encountered as had been previously experienced by others working with the wet process. Corrosion was the most troublesome and it took two years of constant effort and trial on the part of the experimenters to overcome this part of the problem. Many different corrosion resisting metals, alloys, and nonferrous materials were tested in the laboratory. Wood, glass, tile, rubber-lined steel pipe, asbestos, bakelite, cast iron, copper, and many other ma-

terials were tried out for various parts of the equipment with varying degrees of success.

Erosion of the parts together with the temperatures encountered complicated the problem and retarded the finding of suitable materials. However progress was steadily made and has resulted in a commercial apparatus. After the installation on the first two boilers at Kneeland Street Station, the Edison Company showed their confidence in the apparatus by equipping their new 350,000 lb. of steam per hr. boiler with the same type of scrubber.

During the trials, it was found that a positive means must be provided for settling the dust out of the water. So-called Callow cones developed in the metallurgical industry were installed and have solved the problem nicely. These cones concentrate the dust into a small quantity of underflow water 4 to 5 gal. per min. per scrubber and deliver the rest of the water containing from 0.02 per cent to 0.15 per cent of solids by weight, to the recirculating pumps. Later developments indicate this will be reduced to about 0.06 per cent or 0.08 per cent by weight.

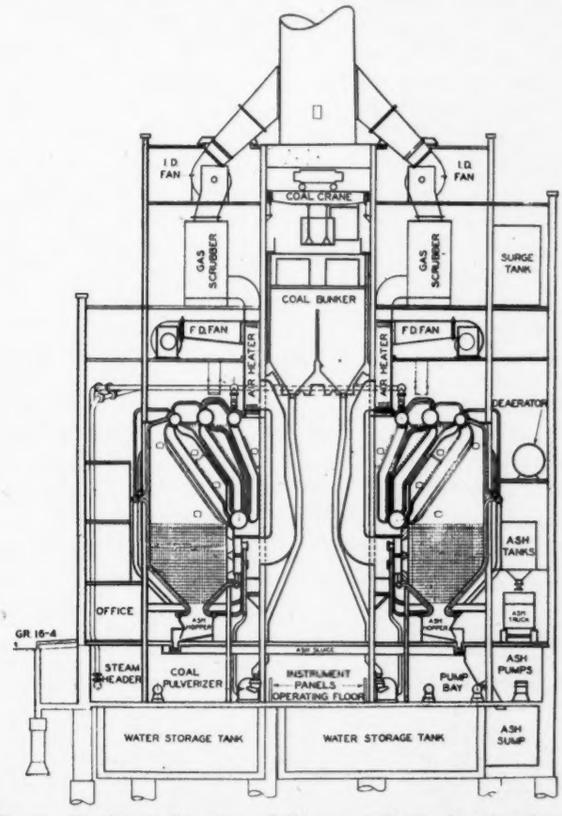


**Fig. 4—Sectional elevation of Kneeland Street Station showing location of gas scrubbers for two boiler units.**

Because of the acid and the solids in the recirculated water, special pumps were used for the purpose. The first pumps with impellers and casings of Elcomet K soon failed because of the intercrystalline corrosion in the propellers. Others were equipped with Illium, and phosphor-bronze propellers and hard lead casing with varying periods of life. From this experience was developed a pump which has operated for over eight months without trouble and appears to answer the pump problem.

The total acidity of the recirculated water, calculated as sulphuric acid, varies only from 0.1 per cent to 0.3 per cent at all loads. It is mostly sulphuric with traces of sulphurous, hydrochloric, nitric and hypochlorous acids. It was believed the causes of the severe corrosion were due to these small amounts of acids other than sulphuric and this delayed the development until suitable materials could be found to resist them.

A microscopic examination of the dust collected in these scrubbers has proved most interesting. The fine particles were magnified to 400 dia. and appear to consist of small spherical particles, coke, and many extremely fine particles. Much of the dust varies from 3 to 5 microns in dia. When it is considered that a particle which just passed through a 325 mesh sieve is 43 microns in dia. an idea of the fineness of the material collected is obtained.

Although developed primarily for use with boiler flue gases, this type of scrubber may prove effective and economical when used for other purposes such as smelter fume recovery, and gas treatment at metallurgical and chemical plants, elimination of dust nuisances around cement plants, and in fact wherever a dust nuisance constitutes a problem.

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**John B. Foley, Jr.,** 510 Hills Building, Syracuse, N. Y., has been appointed Syracuse district sales representative for the power plant equipment division of The Swartwout Company.

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## Obituary

Edwin Nash Sanderson, president of the Federal Light and Traction Company for more than 20 years, and member of the engineering firm of Sanderson & Porter, which he and H. Hobart Porter established in 1896, died at the New York Hospital Wednesday evening, November 9th, at the age of 69.

For more than 30 years Mr. Sanderson had been prominent in public utility and industrial enterprises. Before he formed his own firm he was employed by Westinghouse Electric and Manufacturing Company, first at Pittsburgh and then at Boston. As president of the Federal Light and Traction Company he was also at the head of its 30 subsidiary operating utility companies, including electric light, power, railroad, gas, water and ice properties in the United States and Canada.

Mr. Sanderson was a fellow and life member of the American Institute of Electrical Engineers, a member of the American Society of Mechanical Engineers, Rensselaer Society of Engineers and the Cornell Society of Engineers.

# Patents*

By GEORGE RAMSEY
NEW YORK
Patent Lawyer
Member A. S. M. E.

**In this installment Mr. Ramsey discusses responses to the Official Action of the Examiner on an application for patent. The routine of filing amendments and affidavits, the formal requirements of the Patent Office covering such documents and their limitations as to nature and scope are all set forth in detail. In general this article may be said to cover the various means available to the patentee for correction of faults in his original application and for answering the criticisms or causes of rejection cited by the Examiner.**

## PART V

### Patent Office Procedure (Continued)

*Response in Six Months*

The Official action from the Patent Office is mailed to the attorney of record. The law requires that a response to this action must be in the Patent Office within six months from the Mail Room date on the action. There is a slight advantage to attorneys living near Washington because a little of the six month's period is consumed by the mail. However, with high speed trains and airplane mail now available, the difference is not as great as it was some years ago. Where the six month's period terminates on a Sunday or a legal holiday in the District of Columbia, the date limit for response goes over to the next succeeding day. It is seldom advisable to wait to the last day to respond to an Official action. Sometimes, however, the six months goes by and a late response becomes necessary. The Patent Office has provided a mail box at the watchman's desk so that special delivery letters may be received and placed in this box. All mail or documents placed in the box before twelve o'clock midnight are stamped by the Patent Office on the following day as though they had been received on the preceding day.

In order that a response shall be effective, it must be full and complete, and each point raised by the Examiner must be traversed in some proper manner. Where the response is incomplete or is not made within the six month's period, the application to which it refers becomes abandoned. That is, the applicant has lost his right to a patent on this application. This may be a serious matter. It may be too late to file a new case because of public use or some prior publication or for some other reason. If a reply is filed near the end of the six months' period, the amendment will usually be looked over by the Examiner to see if it is a complete response. If the Examiner decides it is incomplete and there is sufficient time remaining for the applicant to act, the Examiner will notify the attorney and call his attention to the date upon which complete response expires. The attorney is thus placed on notice to amplify the reply to cover all points raised by the rejection. When a case is abandoned, its continuity ceases so far as divisional or relative cases filed after the abandonment are concerned. If divisional cases have already been filed, before the parent case abandons, the divisional cases will retain the date of the parent case as the effective filing date of the divisional cases. Any alleged divisional cases filed after the date of abandonment are not recognized as divisions of the parent case, and do not get the benefit of the filing date of the parent case. However, if the parent case should be revived through special act of the Commissioner, then the divisional cases will take on the filing date of the original case.

*Right to Amend*

The applicant has a right to amend as soon as his application is filed, that is, either before or after the first action by the Patent Office, and he may amend as often as the Examiner presents new references or reasons for rejection. All amendments must be in writing, preferably typewriting, and must be written on one side of a sheet of legal cap paper and should contain no erasures or any long hand interlineations. Amendments to a prior amendment are not permitted except where an entire page or a large part of a specification was rewritten by a prior amendment. This rule is to obviate confusion or error when the amended specification is printed. If necessary to amend an amendment already made, it is best to request that the prior amendment be cancelled and then direct the proper amendment to be inserted in the proper place.

All amendments to an application are required

* All Rights Reserved by Author.

by the rules to be in permanent ink, although the Patent Office will accept an amendment not in permanent ink such as a carbon copy providing a permanent ink draft is filed before the application is allowed. Amendments are usually submitted in the form of typewritten documents. The Patent Office, however, will receive a telegraphic amendment providing a typewritten confirmation amendment is subsequently filed. Amendments must specifically designate the cases to which they belong. If an amendment should accidentally be directed by mistake to a wrong case, it cannot be later withdrawn from that case and introduced into the case for which it was intended. Therefore, if there are two applications, one of which requires a response within a short time and the other of which has a longer time before response is required, and the heading for the amendment should accidentally be designated in the case having the longer time, whereas it was intended for the case requiring prompt attention, and this error is not discovered until after the end of the six months' period, the amendment cannot be transferred and the case for which it was intended will be abandoned. Care and accuracy are therefore essential.

Amendments submitted must be entered by the Patent Office as a whole or not at all, that is, if an amendatory paragraph of several lines or pages be submitted, the Patent Office cannot accept the first page or part of the amendment and reject the remainder. However, the Patent Office may, out of a large number of separate amendments set forth in a single response, refuse to enter specific amendments on the ground that they refer to new matter or for some other reason, but an individual amendatory phrase, clause, or sentence must be either entered as a whole or not at all. It cannot be entered in part. Amendments must be actually signed either by the applicant or the attorney of record or an assignee of record. Rubber stamp or typewritten signature names will not be accepted.

If an unsigned or an improperly signed amendment reaches the Patent Office, it will be returned to the attorney for signature, providing there is sufficient time before the expiration of the statutory period for the amendment to be signed and returned to the Patent Office. If there is not sufficient time, the response will not be entered in the file of the application, but will be endorsed on the record as received and the applicant or his attorney promptly notified of the status of the case.

In amending an application to amplify the same, the specification and claims may be amended to include features illustrated in the drawings, but not adequately described or claimed. Conversely, the drawings may be amended to illustrate any construction specifically described, but not originally illustrated. No change of any kind whatever can be made in the drawings without first filing a photographic copy of the original drawings and then the change can only be made after the proposed change has been approved by the Examiner. After filing photographic copies, the original drawings may be withdrawn to make such corrections as cannot be made by the drafting department of the Patent Office. The proposed change may be shown by sketching on a photographic copy of the original drawings or by a separate sketch which is filed in the case to show what the proposed change shall be. Such sketches must be in permanent ink. Substitute drawings in a case will not be permitted unless required by the Patent Office.

After the application is completed, the Patent Office will not return the specification and claims for any purposes whatever. If the applicant has not retained copies of the specification and claims as filed, the Patent Office will furnish such copies to the applicant upon the payment of a fee prescribed by law. The Patent Office is provided with photostatic apparatus and it is usually best to obtain the photostat copies of any material desired from the Patent Office. A photostat makes a true copy so there can be no confusion between the document in the Patent Office and the copy in the hands of the applicant.

### *Essentials of an Amendment*

Each amendment should bear a heading comprising the applicant's name, the title of the invention, the serial number of the application, the filing date, also the Division of the Patent Office and room number of the Division to which the case is assigned. All of this information may be obtained from the heading of the Office action. The amendment should also designate the date of the Office action to which the amendment is in response. Each amendment to the specification and claims must designate specifically the exact word or words to be stricken out, changed or inserted and the precise point where the amendment is to be effective. For example, suppose the sentence originally read "The frame (1) carries a shaft (2)." Suppose the Examiner required further description or that the applicant wished to amplify this description, and the drawings clearly showed that the frame was a main frame which carries the main operating shaft, and further suppose that this sentence occurred on page 5, line 9 of the specification. The amendment would read: "Please amend this application as follows:—Page 5, line 9, after 'the' insert—main—. Page 5, line 9, cancel period and add—'which drives suitable gearing adapted to rotate a counter shaft (3)'.—" The amended sentence would now read: —"The main frame (1) carries a shaft (2) which drives suitable gearing adapted to rotate a counter shaft (3).—" It sometimes happens that a simple change on one page of the specification will necessitate a large number of changes elsewhere. It is necessary in making an amendment to be certain that the remaining description is consistent with the amendment which is made.

It is not unusual in the prosecution of applications to cancel claims submitted from time to time and to add new claims. The original claims were numbered consecutively, and each new claim added must bear a consecutive number. For example, if the original application carried fifteen claims, and four of these claims were cancelled and two new claims added, the new claims would be numbered "16" and "17." Then, if there were a later amend-

ment adding another new claim, this claim would be numbered "18" and so on.

Following the body of the amendment, specifying changes to be made, comes a heading "Remarks" and under the heading "Remarks" the attorney will set forth his arguments in support of a request for reconsideration as to such claims as he feels were not properly rejected. Occasionally, an amendment will be filed in which amendatory subject matter and argument are mixed. This is not good practice because all amendatory subject matter is entered by the Division Clerk into the original application in the properly designated places. "Remarks" are merely argument and not a part of the specification or claims. Therefore, it is better practice to group all amendatory subject-matter together and all argumentative subject-matter in another portion of the response.

*Response to Request for Division*

Assume that the first action in the case is merely an action requiring division. The Examiner usually will divide the claims into groups and designate the group of claims to be examined in one class in one Division and a group of claims to be examined in another class in the same or a different Division, etc. The Examiner will usually cite one or two patents illustrating the character and type of inventions examined in each particular group designated. Division may also be required, as previously explained, between claims to different species of an invention.

A proper response to an action for division may take three forms. First, the applicant may accept the ruling of the Examiner, in which case, he will cancel all of the claims excepting those in the particular group which he has chosen to prosecute in this application. He will also cancel from the specification and drawings such subject-matter as relates to the claims which have been cancelled. In other words, he will amend the application so that it is restricted to a single invention.

An action for division is one which may be reviewed on appeal. Therefore, the second course which an applicant may take in response to division is to "elect" to prosecute a certain group of claims in the application while retaining the other claims in the case until a final action is reached, at which time the question of division may be taken to an appellate tribunal for determination.

The third course which the applicant may take is to request reconsideration. A request for reconsideration of the requirement of division must be based upon a definite and fully written argument in support of the applicant's position and in opposition to the Examiner's requirement. For example, suppose an application discloses an ingot mold and a steel ingot and that certain of the claims in the application cover the mold and certain other of the claims cover the ingot. The Examiner, in this case, may require division. A proper response is to point out that while there were two inventions set forth and claimed in the application, namely, the mold and also the ingot, these two inventions were so closely related that it is proper for both inventions to issue in a single patent because when a mold manufacturer is preparing to make a new ingot mold, his inventive thought is usually directed first to the ingot and then to the mold since the ingot necessarily must assume the shape and contour of the mold. Therefore, while there are two separate inventions in the application, the subject-matter and the mental concept of the invention are so closely related as to properly belong to a single entity. Furthermore, the search made by the Examiner for prior references which apply to claims on the mold will cover ingots. It, furthermore, may be pointed out to the Examiner that if a patent issued with claims directed only to the mold, or claims directed only to the ingot, the inventor would not have complete protection on his invention. Where the patent covers only the mold, the molds could be used in Canada to cast ingots which could be shipped to the United States for fabrication and the inventor would have no redress. On the other hand, if his patent were restricted to the ingot, then the mold could be made in the United States and shipped to Canada to be used to manufacture ingots fabricated in Canada, and, in this case, the inventor would have no redress. Under these conditions, requirement for division is usually waived.

Where division is required and the applicant desires to respond by cancelling the divisible subject-matter, he need not give up a patent on the divisible matter, but may file divisional applications as we have previously explained, covering the divided out subject-matter and these divisional cases take the date of the original application, so far as common subject-matter is concerned. The principal reason for resisting the requirement of division is the danger of "double patenting." Requirement by the Patent Office is no excuse in Court. This question often requires careful analysis by a competent attorney to determine whether to abide by the Examiner's ruling or to appeal therefrom.

*Response to Action on the Merits*

Assume that the first Office action was not a requirement for division, but was an action "on the merits." Such an action criticizes the specification for misspelled words or lack of clarity or any other proper criticism, and also comprises a citation by the Examiner of prior art patents against the claims. In other words, the Examiner usually takes the position that the claims in their present form do not define invention over certain specific prior art. The attorney orders copies of the United States patents from the Patent Office and if publications or foreign patents have been cited, photostats may be obtained. After these references have been received and carefully studied, the character of the response is dependent upon the conclusions reached by the attorney. If the attorney concludes that the references completely anticipate certain claims, these claims may be cancelled. If he concludes that by a slight change in the claims, they may be worded to avoid the references, he will amend the claims by inserting specified de-

scriptive terms or phrases in designated portions of the claims. If he concludes that certain of the rejected claims are not met by the references or in other words, that these claims define an invention not to be found in the references, he will request reconsideration of these claims.

The ordinary response to a rejection on the merits is an amendment more clearly defining the invention or an argument showing the alleged prior art does not anticipate. It frequently happens that the difficulty is not so much in the similarity of the invention to the prior art as it is a matter of the language used in the claims. In other words, inadequate language may be used in the claims so that the claims read on the reference cited, but once the reference is before the attorney, he may see that by changing a word here or there, the applicant's invention may be more clearly defined and that the new definition will not conflict with the prior art cited. For example, it is a perfectly easy matter, as a matter of words, to draw a claim which will read on both a picket fence and a fine tooth comb, but this similarity of language does not, of course, mean the two objects are the same. It is easy enough to distinguish one from the other by proper language as well as to confuse the two by improper wording. After an application has been prepared, and executed, if errors should be discovered, two courses of procedure are open dependent upon the character of the errors or omissions. The application may be filed and then amended; or the formal papers may be destroyed, the application rewritten and re-executed. If the errors or omissions are merely informalities such as misspelling of words, or bad grammar in a sentence, or lack of complete clarity as to some statement, all of these features may be corrected by an amendment. In any event, an executed application must not be changed in any way after it is executed and before it is filed. It is no excuse that the directions for making the change came from the inventor and were in writing. If the application requires a substantial change, such as the inclusion of a new claim, or the addition of some element which was not disclosed, then the only thing to do is to destroy the formal papers signed by the inventor, rewrite the case to include the added feature and have the case re-executed. Under these circumstances, no amendment will cover the situation and if an attempt is made to fill in these omissions after the application is executed and before it is filed in the Patent Office, the application will be stricken from the files. The facts concerning an application are often brought out if there should be an interference proceeding (which we will discuss later) in which the application is involved.

There was an interference between two inventors in which was involved an application which the inventor executed and mailed to his attorney, and with the letter of transmittal the inventor wrote out the substance of a claim which he felt should be placed in the application. The attorney took the substance of the suggestion of the inventor and added a claim to the executed application before it was filed in the Patent Office. This was brought out in testimony and the case was stricken from the files.

### *Supplemental Oath*

Amendments to an application, therefore, must be within the disclosure of the application and the changes which may be made after the citation of references are changes in language rather than in substance. It sometimes happens that some feature of an invention disclosed was not originally claimed, but might be properly claimed by way of an amendment. Since the original oath covers the invention claimed, and since the particular subject-matter now specified was not originally claimed, it becomes necessary to file a supplemental oath before the Patent Office will accept claims to this subject-matter. This supplemental oath must set forth facts showing the subject-matter of the proposed claims was part of the invention, was invented before the original application was filed, was not known or used before the invention, was not patented or described in a printed publication in any country more than two years prior to the filing date of the application, and was not patented in any foreign country on an application filed by the inventor or his legal representatives or assigns more than twelve months prior to the filing of the United States application, was not in public use or on sale in the United States for more than two years before the filing date of the application, and that the newly claimed invention has not been abandoned. This supplemental oath which may be made by anyone who had legal authority to make the original oath must be attached to and properly identify the proposed amendment adding the new claims.

There are many decisions of the Courts where a patent has been held to be invalid because of a lack of a supplemental oath before the patent went to issue. If there has been considerable amending to the claims and specifications, it is advisable for the inventor to carefully review the claims and specification before the case becomes a patent and to file a supplemental oath covering the case as it stands in final form.

### *Swearing Back of a Reference*

Where the claims in an application are rejected on a United States patent, which discloses but does not claim the rejected invention, or on a foreign patent, or a printed publication, provided the date of the patent or the publication is not more than two years prior to the rejected application, the inventor may take oath to facts showing completion of an invention in this country before the filing date of the said United States patent or before the date of the foreign patent or the date of the printed publication, and that he has never abandoned the invention. When such an affidavit is filed, the reference will be withdrawn. This procedure is known as "swearing back of a reference." In order to properly "swear back of a reference," the applicant must furnish sufficient evidence to make a *prima facie* case of completion of the invention in this country before the date of the reference.

In other words, he may file photographs of a completed machine, which photographs are properly identified with descriptive matter set forth under oath or he may file blueprints or other documentary evidence of the completion of the invention.

*Affidavit on Operativeness*

Where an invention is rejected on a prior patent, which upon careful study is found to disclose an inoperative device or an inoperative chemical composition, an argument may be presented pointing out the features of the reference which render it inoperative. It frequently happens, particularly with reference to chemical compositions that the argument of inoperativeness should be supported by facts concerning carefully conducted experiments, the results of which are set forth in an affidavit which is submitted with an argument requesting the withdrawal of the reference on the basis of inoperativeness. An alleged reference which is inoperative is not a prior art reference. The prior art constitutes the workable knowledge of the art before a specific date. That is, the prior art applicable to an application includes all workable known devices in the particular art prior to the date when the application was filed in the Patent Office. An inoperative device disclosed in a patent, therefore, is not a part of the workable prior art upon which the rejection can be based.

The same procedure is followed to traverse an action where the device of the application is rejected as being inoperative. In this case, the rejection by the Examiner may be overcome by supplying affidavits of experiments showing the invention is operative or of experts in the art who may submit a sworn statement carefully analyzing the device and pointing out its correct method of operation.

*Affidavit as to Commercial Use*

Where the claims of an application are rejected as not constituting "invention" over some prior art reference, it is not unusual to meet such a rejection by submitting an affidavit showing the extent of commercial use of the invention disclosed in the application. This same procedure is often followed where the Examiner considers the invention as frivolous or lacking in utility.

Occasionally, an application is incomplete due to the omission of some feature which is very well known in the art. In this situation, it may be necessary to file an affidavit to the effect that the required addition to the application is not new matter, but is of such character as would obviously be supplied by one skilled in the art to correct an obvious error.

It was said that some years ago, an inventor attempted to obtain a patent for the use of gold as a reflector for a certain type of searchlight. His application was rejected on the basis that he had merely made a substitution of material; that various polished metal surfaces had been used for reflecting surfaces; and that to choose one metal or another metal was merely the choice of the workman and did not constitute invention. He thereupon dropped his application and it became abandoned. At a somewhat later date, another application for patent was filed by another inventor claiming the use of a gold reflector for a searchlight and asserting that he obtained very unusual and improved results with a gold reflector when the searchlight was used in fogs and mist. This application was also promptly rejected for the same reasons as was the prior application. The later applicant, however, responded to that rejection by several affidavits, some from optical experts and some from officers of a certain foreign navy where it was stated this searchlight had been tested. These affidavits asserted that gold had the peculiar characteristic of changing short wave lengths of light into longer wave lengths of light, and that, therefore, the beam of light from the gold deflector searchlight was enriched with long wave length rays. These long wave length rays were not so easily absorbed by the atmospheric mist as were shorter light waves. Consequently, this gold reflector searchlight delivered a more effective beam than the ordinary silver reflector searchlight. The affidavits were convincing and the second applicant secured his patent. This incident is offered not as an exposition of an alleged scientific fact but merely as a narrative to show that it pays to persist in attempting to arrive at an end providing the end justifies the efforts necessary to reach it.

Affidavits, ordinarily, are not a common run of response to rejections and should not be used over extensively. Like other good things, they have their proper place and use.

*Design Application Changed to Utility Application*

While an applicant is not entitled to amend a case so as to change it in substance from one invention to another, there was a situation wherein an applicant who attempted to prosecute his own case and inadvertently filed a design application was permitted, by the Patent Office upon the proper payment of fees, to amend his case so that it became an application for a utility patent. This procedure was permitted, under the circumstances, and in view of the fact it was evident that the applicant thought he was making an application for a utility patent whereas as a matter of form his application was for a design patent.

*New Matter Cannot be Added by Amendment*

The great difficulty to be continually guarded against in amending an application is to obviate the introduction of "new matter." In other words, the amendments can only be made within the disclosure of the original application. If they go beyond this boundary, then any patent issuing thereon is likely to be considered as invalid. However, doubts are usually resolved in favor of the inventor, especially in border line cases and the added material relied upon to invalidate a patent, must be clearly "new matter." The rule against new matter, however, is so strict that an applicant will not be permitted to omit an element from his case where the omission of the element might change

the operation of other parts and might produce a new invention.

Where it was found that the description of the machine was not correct and that it would not operate as described and that, through a clerical error, the parts of the machine were misnamed, the Patent Office permitted an amendment correcting these errors and the addition of another view of the drawing more fully disclosing the construction. It is not unusual for the Examiner to require an additional view of the drawings which will more clearly disclose the operation of certain parts of a machine. While such a view of the drawing shows something that was not clearly shown by the original views, such an amendment is not new matter, but is a mere amplification of what is already disclosed. A correction of the theory of a method or operation of a machine is not new matter. As has been stated, if an application issues as a patent with a wrong theory as to the operation of the machine, such patent will not be held void for this reason, providing the specification sets forth sufficient information to permit one skilled in the art to practice the invention when the patent expires. While it has been permitted to add by amendment the description and claims to a process in an application wherein the process was closely allied to the apparatus, without the patent being declared invalid because of new matter, this is not a safe practice. The Supreme Court of the United States in dealing with a situation of this kind found a patent on the process of burning acetylene to be invalid where the original application had claimed the form of burner and the attorney in amending the case in view of prior art, changed the claims to process claims. The Supreme Court held that the history of the patent in the Patent Office showed that the attorney introduced by amendment not only the theory on which the process was based, but also the mode of applying the theory, which was in effect the process itself, and that since the original application did not clearly disclose this process, the patent was void.

### *Return Post Card Acknowledgments*

After the amendment has been prepared, it must be mailed to the Patent Office to reach the office within the statutory six month's period, but the Patent Office does not acknowledge receipt of amendments. Therefore, the attorney or the applicant may wonder if the amendment reached the Office within time. The Patent Office, however, will stamp a date stamp on a self-addressed post card forwarded with an amendment. The return of this post card to the applicant or the attorney with the Patent Office date stamp thereon comprises an Official acknowledgment of the amendment to the case identified on the post card and obviates any anxiety as to the proper receipt of the amendment by the Patent Office.

This return receipt post card also has another very important use. The Patent Office handles hundreds of thousands of pieces of mail during the year and great care is exercised. Occasionally, however, the file becomes misplaced or an amendment may be misplaced. If an amendment should be misplaced, there would be no record on the file of the application showing such an amendment had been filed. The return post card, however, duly stamped by the Patent Office would constitute evidence that the amendment was filed and would afford a basis upon which an abandoned case could be revived.

Some years ago, an application file disappeared. This particular incident happened in the Interference Division. The entire Patent Office practically stopped work for two days while a search was made for the lost file. Along toward the close of the second day, someone looked beneath the cushion on the chair of the Examiner of Interferences and there reposing peacefully was the lost file.

While the author was a member of the Examining Corps, a file for a lighting device disappeared from Division 30. The entire Patent Office was searched for this file. One morning many months after the file had disappeared it was found lying in the middle of the desk of an Examiner examining farm machinery, three floors away and in the opposite corner of the old Patent Office Building. It was never explained where the file had been nor how it reached this desk so far from its proper place.

In view of the above circumstances, it will be seen that it is decidedly advisable to have a post card receipt of everything filed.

When the amendment reaches the Patent Office, if it is in proper form, it will be filed in the application. The application will then be known as an amended case and will take its proper date on the Examiner's desk when it will be reached for re-examination in chronological order.

The Official Gazette of the Patent Office published each week carries a tabulation showing the status of the work in each Division, and showing the date of the oldest new application (this being an application which has not been examined) and the date of the oldest amended application pending in each Division. Where an application has been amended for a relatively long period and no response by the Patent Office has been made, it is advisable to consult this list to see if the Division in which the case is pending is reporting dates which have passed the date on which the case was amended. If the Patent Office has passed the date, then it is advisable to make an immediate inquiry to find out why the case has not been acted on. It may be that the case for some reason or other has been transferred to another Division which is further back in its work or it may be that the case has been inadvertently overlooked or again, it is possible that the amendment has been misplaced or did not reach the Patent Office. A prompt inquiry, under the above conditions, will obviate any difficulties which might arise through something having gone wrong.

### *Oral Interviews With Examiner*

As has previously been stated, all business with the Patent Office must be conducted in writing. However, it is occasionally desirable that the Examiner be interviewed in connection with a par-

ticular case. Interviews facilitate bringing about a better understanding between the attorney and the Examiner and often lead to an agreement as to form of claims which may be allowed, which end in some cases could not readily be reached by correspondence. Where an interview with the Examiner occurs, the results of the interview should be referred to in the remarks accompanying an amendment presented in accordance with the interview.

The Patent Office does not recognize any oral statement made by the Examiner during an interview as being conclusive. However, where an Examiner agrees to allow claims, if amended in certain form, the Examiner usually does not reject these claims unless a new reference is discovered. It is not advisable to seek interviews in every case and the Patent Office discourages needless interviews because they use up valuable time of the Examiner. An interview should only be resorted to in cases where it is believed the business of both the Office and the applicant will be expedited by such a conference.

*Amended Applications Re-Examined*

The amended application is taken up and re-examined by the Examiner. Another Official action is written in the case in view of the amendment. This procedure of amending and rejecting goes on until the Examiner takes a final action in the case. This final action may be an allowance of all the claims in the application. Where this occurs, the application is said to be "passed to issue".

It may be the Examiner decides after a re-argument by the applicant or his attorney that he will stand on his original ground and that he will not allow certain claims for which the applicant is insisting. Under these conditions, the Examiner gives what is known as a "final rejection", and the prosecution of the case before the Examiner is practically closed.

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## Steam-Table Research Nearing Completion

The most elaborate, careful, and complete investigation into the thermal properties of steam ever attempted will soon be brought to a close after twelve years of work. This was revealed at a meeting in headquarters on October 25 of the Technical Subcommittee of the A.S.M.E. Special Research Committee on the Thermal Properties of Steam. An early revision of the international skeleton steam table was foreshadowed in the reports made by Dr. N. S. Osborne, from the Bureau of Standards, and L. B. Smith for Dr. F. G. Keyes, from the Massachusetts Institute of Technology, where the experimental work has been carried on.

The vapor pressure curve of water now seems to be very well established, practically to the critical point. A new series of measurements have been made by different methods at the two laboratories, and the results are in excellent accord. They have been checked with recent results reported by British and German workers and pave the way for revision of the international skeleton table. This work will be discussed at the Steam Table Session during the coming Annual Meeting.

It is also felt that the data on specific volumes of liquid water and water vapor under pressure are now complete up to 300 atmospheres as the result of the past year's work at Massachusetts Institute of Technology. The experimental program there is now virtually finished. All that remains is to compute and correlate the mass of data obtained, and it is estimated that this will be completed by July 1 of next year.

At the Bureau of Standards there remains to be completed the measurements of the total heat of the liquid, the latent heat, and the pressure-temperature relationship for saturated steam in the range between 800 lb. per sq. in. and the critical point. It is estimated that this work, coupled with the necessary computation and correlation of data, will require a year to complete. The elaborate precaution taken to secure experimental data of unquestionable accuracy has been one of the distinguishing characteristics of the experimental work at the Bureau and the Institute.

The Third International Steam Tables Conference scheduled to be held in the United States this last September was postponed because economic conditions made it impossible for the foreign cooperating organizations to participate. Every effort will be made to hold the conference next year, however, as there is much new data that need correlation. A much further narrowing down of the tolerances in the international skeleton table seems probable. It will be some time after that, however, before new steam tables are published. At present there are several tables, recently published, that give values within the present limits of the skeleton table—namely, those by Hausen and Mollier in Germany, Callendar in England, and Keenan in this country. The latter is published by the Society.

The value of this international research to science and industry is incalculable. Basic reliable data have been presented taking the guesswork out of designing equipment for the use of steam at high pressures and temperatures. Industry has contributed to the American investigations alone close to $175,000 since their beginning in 1921. The scientific and engineering world are lastingly indebted to the foresight, energy, and persuasiveness of Alex Dow and Geo. A. Orrok, who successfully undertook the burden of raising these funds. It is estimated that due to the extremely high limits to which the experimental determinations have been carried, the accuracy of these values, and the independent checking that has been accomplished by the various investigators, the resulting steam tables will stand for the next 50 years.

*(Reprinted from November 22nd issue of the A. S. M. E. News)*

# Derivation and Use of Common Formulas Used in Combustion Calculations

## PART 2

### Formulas for Calculation of the Amount of Air Required and Used for Combustion

By P. B. PLACE, Engineer

Combustion Engineering Corporation

THE usual formula used for calculating the amount of air required for the complete combustion of a fuel is;

$$(1)\quad \text{Required air} = 11.5\,C + 34.5\left[H_2 - \frac{O_2}{8}\right] + 4.3\,S$$

in which C, $H_2$, $O_2$, and S are the weight fractions of these elements as given in an ultimate analysis of the fuel. This equation is essentially a summation of the amounts of air required for the three combustible elements of all fuels, carbon, hydrogen and sulphur, and each item in the equation may be dealt with separately.

The chemical equation for the oxidation of carbon by oxygen is

$$\begin{aligned} C + O_2 &= CO_2 \\ 12 + 32 &= 44 \\ 1\text{ lb.} + 2.66\text{ lb.} &= 3.66\text{ lb.} \end{aligned}$$

This equation states that 1 lb. of carbon requires 2.66 lb. of oxygen to completely burn it to 3.66 lb. of carbon dioxide. This oxygen must be supplied in the form of air which contains 23.18 per cent by weight of oxygen and 20.9 per cent by volume of oxygen. Therefore to supply 2.66 lb. of oxygen we must supply 2.66 ÷ .2318 or 11.48 lb. of air for every pound of carbon to be burned. If 'C' lb. of carbon is to be burned it requires 11.48 x C lb. of air.

Hydrogen combines with oxygen to form water vapor according to the following equation;

$$\begin{aligned} H_2 + \tfrac{1}{2}O_2 &= H_2O \\ 2 + 16 &= 18 \\ 1\text{ lb.} + 8\text{ lb.} &= 9\text{ lb.} \end{aligned}$$

and as before, to supply 8 lb. of oxygen for each pound of hydrogen to be burned we must supply 8 ÷ .2318 or 34.5 lb. of air.

Many fuels contain oxygen either in the free or combined state and to that extent do not have to be supplied with air. In solid fuels this oxygen is assumed to be in combination with hydrogen probably in the unsaturated form, OH. Since it takes 8 parts by weight of oxygen to be equivalent to 1 part of hydrogen, the total oxygen in the fuel is divided by 8 to give its hydrogen equivalent. This hydrogen equivalent is subtracted from the total hydrogen to give the amount of hydrogen for which air must be supplied. Therefore the air required for the combustion of this so-called 'net' or 'free' hydrogen is equal to

$$34.5 \times \left[H_2 - \frac{O_2}{8}\right]$$

Sulphur burns in oxygen according to the following equation;

$$\begin{aligned} S + O_2 &= SO_2 \\ 32 + 32 &= 64 \\ 1\text{ lb.} + 1\text{ lb.} &= 2\text{ lb.} \end{aligned}$$

One pound of sulphur requires 1 lb. of oxygen for its combustion and 1 lb. of oxygen is equivalent to 1 ÷ .2318 or 4.32 lb. of air. To burn 'S' lb. of sulphur requires 4.3 × S lb. of air.

Summing up we find that the total air required to completely burn a fuel is as given in equation (1)

$$11.5\,C + 34.5\left[H_2 - \frac{O_2}{8}\right] + 4.3\,S$$

The assumption that the oxygen is partially or wholly combined with the hydrogen may seem to limit the usefulness of the above equation particularly in the case of fuels containing no hydrogen or more equivalent oxygen $\frac{O_2}{8}$ than hydrogen, such as blast furnace gas. Many fuels contain carbon monoxide and carbon dioxide, in which the oxygen is known to be in combination with carbon rather than with hydrogen.

Regardless of how or whether the oxygen is in the combined or free state, or whether it is combined with hydrogen or carbon, if we determine the oxygen requirements of the three combustible elements carbon, hydrogen, and sulphur and then subtract the oxygen that is in the fuel and calculate the remainder of the required oxygen to equivalent air we arrive at the same result, namely the air that must be supplied to burn the fuel. Such an equation will take the form;

$$\text{Required oxygen} = 2.66\,C + 8H_2 + S - O_2$$

$$(2)\quad \text{Required air} = \left[\frac{2.66\,C + 8H_2 + S - O_2}{.2318}\right]$$

for any fuel and this equation (2) may be con-

verted algebraically into various forms, one of which may be equation (1) and another may be

$$(3) \qquad 11.5\,C + 34.5\,H_2 + 4.3\,S - 4.3\,O_2$$

One form of the above equation that appears in some handbooks is

$$12\,C + 36\left[H_2 - \frac{O_2}{8}\right] + S$$

which seems to have been adjusted to make it easy to remember without seriously affecting its accuracy.

The amount of air required to liberate a given amount of heat from a fuel is fairly constant for any one type of fuel and for quick estimations, this method of calculation of the required air is useful. Usually 10,000 B.t.u. is the unit of heat liberation taken and the pounds of air per pound of fuel, required for this heat liberation varies with different types of fuels somewhat as follows;

| Type of Fuel | lb. air per 10,000 B.t.u. |
|---|---|
| Coal | 7.5 |
| Fuel oil | 7.1 |
| Natural gas | 7.0 |
| Coke oven gas | 6.6 |
| Wood | 6.7 |
| Blast furnace gas | 5.6 |
| Producer gas | 5.5 |

These values are averages and may vary 10 to 15 per cent. To calculate the air requirements of a given fuel, its heat value in B.t.u. per pound (H) is divided by 10,000 and multiplied by the proper value (A) in the above table.

$$(4) \qquad \text{Required air} = \frac{H \times A}{10{,}000}$$

The amount of air to be supplied for any desired percentage of excess air is calculated from the amount of required air by multiplying by the proper factor, 1.1 for 10 per cent excess air, 1.25 for twenty-five per cent excess air, etc.

The air that has been used to burn a fuel may be calculated from an analysis of the dry products of combustion and an ultimate analysis of the fuel burned. The equation commonly used is

$$(5) \qquad \text{Air used} = \text{Dry Gases} + 9H_2 + R + M - 1$$

in which the 'dry gases' is the pounds of dry gases per pound of fuel* $H_2$ is the hydrogen, R is the total solid refuse and M is the moisture from the fuel in pounds per pound of fuel. The dry gases contain all of the fuel and air except the water vapor formed by the combustion of the hydrogen in the fuel, the moisture in the fuel and the solid refuse from the fuel. If therefore we add to the weight of dry gases, the weight of water vapor from hydrogen ($9H_2$), the weight of moisture (M), and the weight of solid refuse (R) and subtract 1 lb. for the weight of the fuel, we will get the weight of air used for combustion.

For fuels containing small amounts of nitrogen and sulphur, the following formula is given for calculating the amount of air used:

$$(6) \quad \text{Air used} = 3.032\left[\frac{N_2}{(CO_2 + CO)}\right] \times C_b$$

where $N_2$, $CO_2$, and CO are percentages by volume of these constituents in the dry gases and $C_b$ is the weight of carbon burned per pound of fuel. The excess oxygen is represented by the $O_2$ of the flue gas analysis and the difference between the oxygen supplied and the excess oxygen represents the oxygen actually used for the combustion of the fuel,

$$\left[\frac{N_2 \times .209}{.791}\right] - O_2 = \text{Oxygen of air actually used for combustion of the fuel.}$$

If combustion has been complete, this expression also represents the oxygen required for complete combustion of the fuel but if CO is present in the dry gases, the above expression is too low and the required oxygen is as follows:

$$\left[\frac{N_2 \times .209}{.791}\right] - O_2 + CO = \text{Oxygen of air required for complete combustion of the fuel per 100 parts by volume of dry gases.}$$

The percentage of excess air is the ratio of the excess oxygen over the required oxygen or

$$(7) \qquad \frac{O_2}{.2642\,N_2 - O_2 + CO} = \text{Percentage excess air}$$

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**The Century of Progress Exposition** at Chicago has arranged for an "ENGINEERING WEEK" to be held during the last week of the month of June 1933. A Joint Committee of Engineering Societies has been formed in Chicago to stimulate interest in this endeavor and to arrange for the program for a great "ENGINEERS' DAY" when the engineer will be not only entertained but eulogized as well.

Arrangements are being considered to make this occasion of international importance, as many scientists and engineers of world renown will be in Chicago during this time. Other large engineering and power activities for the same week are being arranged. Chicago will be the engineering capital of the world—June 25-30, 1933.

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**The Moore-Handley Hardware Co.,** 25 South 20th St., Birmingham, Ala., have been appointed distributors and direct representatives for the entire Link-Belt general line of elevating, conveying and power transmitting machinery in Birmingham territory. In this capacity they will be prepared to give engineering assistance in the solution of conveying and power transmitting problems.

* See Part I of this series in July issue of COMBUSTION.

# Harvard Engineering School Establishes Fan Testing Laboratory

Establishment of a fan testing laboratory at the Harvard Engineering School, designed to standardize and perfect modern ventilating equipment, was recently announced by Professor H. E. Clifford, Dean of the Harvard Engineering School. The project was undertaken, it is stated, because of the increasing importance of mechanical air and temperature control in modern building construction, where in many cases the traditional windows and ventilators have been abandoned in favor of mechanical ventilation. In addition to this practical application, it is also believed that the new investigations will lead to improvements in fans or blowers used in power plants and industrial processes, and the perfection of propellers used for marine and air transport.

Preliminary studies at the new laboratory, Dean Clifford states, have definitely shown that inlet boxes and ducts commonly used with commercial fans may reduce the capacity of the fan by as much as 50 per cent, and that simple adjustments can result in large savings. Further studies are to consider the effect of air pulsations on fan performance, a subject which is now being considered by the American Society of Mechanical Engineers and the American Society of Heating and Ventilating Engineers. The performance of axial-flow fans is also being studied in detail.

The laboratory has already proved useful to a variety of industrial and community projects by providing an independent agency for fan testing. Such tests have been made for the East Boston Vehicular Tunnel, and the Harvard Medical School Power Plant. It is believed that the laboratory will also prove of usefulness in connection with ventilation equipment for "windowless factories," and modern housing projects.

The following statement by Dean Clifford sets forth the reasons for establishing the laboratory and the nature of the work being done.

"The engineer is frequently confronted with the problem of discharging large volumes of air or other gas against comparatively slight resistances. Common examples are in the ventilation of buildings and the combustion of fuels. The apparatus for this purpose (fans or blowers) has been developed principally by the manufacturers on the basis of elementary theory with but little aid from the scientist. The existing research laboratories in this field are nearly all private laboratories of the manufacturers—the research conducted by them has not been fundamental and has not been published. In view of the need for more exact knowledge of this subject, it has seemed desirable to develop fan-testing equipment at the Gordon McKay Laboratory of the Harvard Engineering School and to start a series of investigations covering both the fundamental aero-dynamic problems and the performance of actual fans. Since fan performance depends largely upon the details of installation and particularly on the form and dimensions of the connected ducts, these accessory parts are also being studied. The equipment of the laboratory has been facilitated by the generous help of the B. F. Sturtevant Company, who have provided fans and ducts for special investigations.

*First investigation has contributed to improved fan performance*

"As with other kinds of machinery, fans are sold under guarantees of performance. The purchaser installs the fan with the belief that it will give its guaranteed performance—rarely does he test it himself. The fan manufacturer's guarantee is made in good faith and is usually based on extensive tests. Nevertheless, it is generally found that the installed fan will not move as much air as was guaranteed and this gives rise to controversies between the fan manufacturer and the fan user. As this matter appears to be the most urgent, it was the first to be investigated. It was apparent that the divergence resulted from differences between the conditions of actual installation and the manufacturers' test conditions. These investigations are now completed and published. They show that inlet boxes and ducts in common use may reduce the capacity of the fan by any amount up to fifty per cent, fully accounting for the discrepancies which have been found between guaranteed and actual results. The investigations have also developed simple, inexpensive devices for restoring the full capacity of such installed fans. These devices are now being tried in a number of power plants and are showing good results. The research engineer of one of the largest public utilities has reported that with an expenditure of $30.00, he is making a saving of $3000.00 per year.

*New standard test code for fans*

"The characteristics of the stream of air discharged by a fan are being studied. It has been commonly assumed that the condition was one of steady flow or that, if there were pulsations, they were not of sufficient magnitude to be of practical importance. The standard methods of measuring air flow are based on this assumption and Standard Test Codes endorsed by various national engineering societies have the same basis. By the use of a vibrograph which photographs the air pulsations and by other means, it has been shown that there are always pulsations in the air flow and that the magnitude of these pulsations may be considerable. Two fans were investigated last year specifically for pulsation and it was found in both cases that considerable pulsation was present and that consequently the volume of air apparently discharged

(as measured according to the Standard Test Code) was about ten per cent greater than the actual volume. This is an additional cause for the disappointing performance of installed fans. A proposed new Standard Test Code for Fans taking pulsation into account has been prepared and printed and is now under consideration by the American Society of Mechanical Engineers and the American Society of Heating and Ventilating Engineers. The development of an improved vibrograph for further research along these lines is another project which is well under way.

*Study of axial-flow fans*

"The outstanding activity of the laboratory at the present time is a study of axial-flow or propeller-type fans. The common ventilating fans, used for keeping air in motion in a room, are of this type but such fans are of no use for discharging air against appreciable resistance. Airplane propellers are of this type but they are designed to give thrust and are not efficient as fans. A successful fan of this type would be simpler and more compact than the usual centrifugal fan. There is reason for believing that it is possible to design an axial-flow fan of high efficiency.

"A windmill is a reversed ventilating fan. In the windmill air arrives with velocity and power is obtained from it; in the fan, power is applied and the air is given velocity. With proper consideration for the aero-dynamic problems involved, the efficiencies of these two procedures should not be greatly different.

"The problems involved in the movement of air and of water are analogous. A marine propeller, like the air propeller, is an axial-flow pump which is designed to give thrust but is not efficient in moving large volumes of water against moderate resistance. In a reversed axial-flow pump, the water arrives with pressure or velocity and does work—such a device is called a water turbine. Axial-flow water turbines (Kaplan turbines) of high efficiency, great simplicity, and low cost have been developed in the past decade and have become an important factor in water power engineering. An axial-flow fan is of the same general form as a Kaplan turbine but is reversed, that is, it absorbs power instead of doing work. The proved high efficiency of the one gives hope for good efficiency of the other.

"The investigation under way involves the determination of the direction of flow and of the velocity of the air at all points in the fan while the fan is rotating at speeds up to 3000 r.p.m., and also the simultaneous determination of the air pressures in every part of the fan. This demands experimental procedures of considerable complexity, but this work is necessary as a basis for the analysis of existing fans and for improving their design.

"The laboratory has proved useful to industry and to the community in providing an independent agency for fan testing. Such tests have been made for the East Boston Vehicular Tunnel, the Harvard Medical School power plant, and others. While this is distinctly a minor or incidental activity, it has considerable value in providing accurate data on fan performance and in increasing the equipment of the laboratory."

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## Salient Features of the New York Power Show

The products of three hundred manufacturers of power and mechanical equipment will be shown at the Tenth National Exposition of Power & Mechanical Engineering, to be held in New York City the week of December 5th. This Exposition takes place concurrently with the Annual Meeting of the American Society of Mechanical Engineers.

Among the distinctly new things to be seen will be control devices of unique design, including a three-element water-level control; a new type of temperature control designed to eliminate hunting; a differential draft-control system; a device for controlling the fuel level in ball mills; and a new type of mechanical steam-flow meter. Many new designs of instruments will be seen, including high-pressure steam gages, fluid meters, condensation meters, recording thermometers and gages for distant pressure recording. Two distinctly new types of expansion joints will be shown for the first time. There will also be on view a superheater especially developed for return-tubular boilers.

The results of research will be reflected in many valves and fittings of alloy steels developed to meet the conditions imposed by the trend toward higher steam pressures and temperatures. Also the progress in welding within the last few years will be depicted by the display of welding fittings and fusion-welded boiler drums.

Those who have experienced trouble through sliming of condenser tubes will find an exhibit of chlorination methods most interesting and instructive. This exhibit will give the visitor an opportunity to see by means of the microscope how the marine growths actually accumulate and how they can be effectively eliminated.

In the line of fuel burning there will be two new types of oil burners, one of the wide-range mechanical-atomizing type and the other of the steam-atomizing type for burning refinery waste.

Among the many other new things, too numerous to list here, may be mentioned a device for removing free air from condenser circulating water; a new type of vibration damper; and a hydraulic coupling for use between motors and fans. One manufacturer, in addition to showing his line of improved products will display, as a feature attraction rather than a commercial product, a thermodynamic motor deriving its power from the surrounding atmosphere. Some other manufacturers are planning surprise features which they are not announcing in advance but which will add to the interest of the show.

# Description of Steam Generating Units for New Washington Heating Plant

**In April of this year announcement was made that the United States Treasury Department had awarded contract for complete steam generating units to be installed in the Triangle Heating Plant, Washington, D. C. The original award contained an option for two additional units, which option was exercised by the Government in July of this year. The final design of these units has now been completed and details are published in the accompanying article. The actual installation is scheduled for completion by October, 1933 . . . . The Triangle Heating Plant will provide heat for the various buildings included in the new Federal building development. The government architects and engineers have designed this plant so that it will harmonize with the architecture of the surrounding buildings in the new development and have taken particular pains to make it a model plant in every respect.**

THE steam generating equipment for the new central heating plant for public buildings at Washington, D. C., to be known as the Triangle Heating Plant, will comprise six stoker-fired boiler units, the design of which has now been completed. The boilers are of the sectional-header type and are designed for a working pressure of 400 lb. per sq. in., although the initial operating pressure will be 200 lb. Each boiler is 45 tubes wide and 20 tubes high; the tubes are 24 ft. long. The drums are 60 in. inside dia., 32 ft. 7 in. long (shell length) and will be of fusion-welded construction throughout.

Each furnace is 18 ft. 6 in. deep (front to back) and 26 ft. 6 in. wide. Eleven water-wall tubes, paralleling the slope of the stoker, are to be installed in each side wall. The lower seven tubes are faced with cast-iron integral furnace blocks, the four upper tubes being uncovered. These tubes connect into downtake and riser headers outside the setting. The rear wall, for its full height, is protected with 4-in. tubes spaced horizontally on 7-in. centers. The lower portion of these tubes, exposed to the ash pit, is also protected by integral furnace blocks which extend up to a point even with the block facing on the side wall tubes. Above this point the tubes are bare. These wall tubes connect into lower and upper junction headers outside the setting.

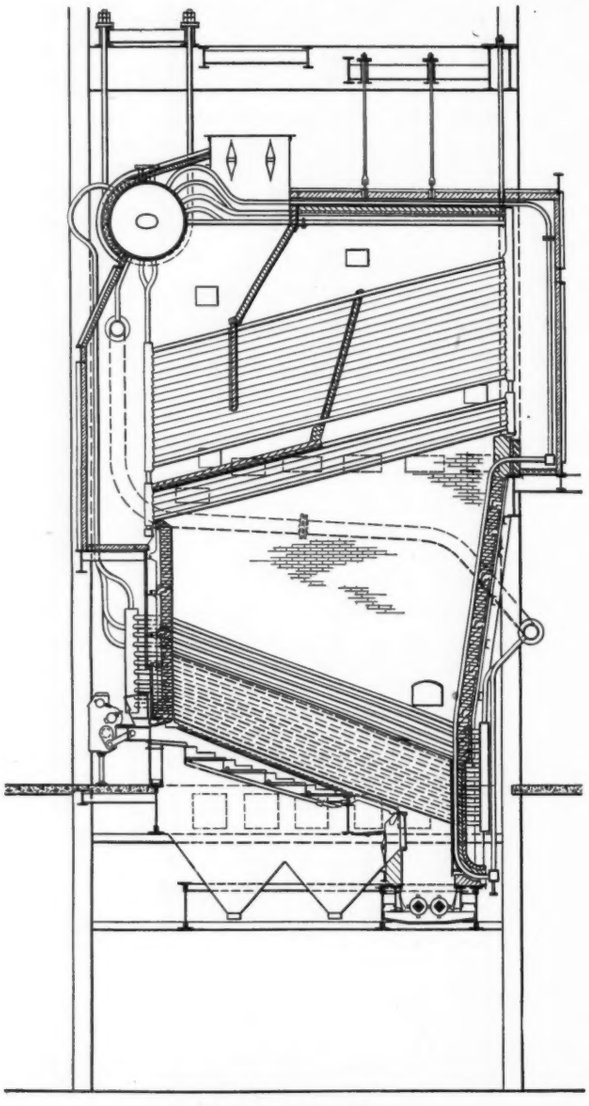
All six furnaces are of the suspended refractory type. The front walls of each furnace are air-cooled with natural circulation. Both side walls from a line about even with the bottom boiler tube bank down past the stoker are of the same construction. Air is induced at the top and drawn downward by the forced-draft fan suction. The walls above the air-cooled sections of the side walls, are of solid, suspended, refractory construction. The rear furnace wall is also of solid, refractory, suspended construction. The entire exterior surface of the units, including the roofs, is steel-encased.

At 200 lb. pressure, the guaranteed maximum continuous evaporation of each boiler is 215,000 lb. of water per hr. from and at 212 fahr. The maximum guaranteed evaporation for a two-hour period is 237,000 lb. per hr., and the normal continuous evaporation is considered as 129,000 lb. per hr. The stokers are of the multiple-retort underfeed type, are 15 retorts wide and have a projected area of 485 sq. ft., or an actual area of 512 sq. ft. The two-hour peak load will require the burning of approximately 21,000 lb. of coal per hr. This corresponds to a furnace liberation of approximately 32,000 B.t.u. per cu. ft. per hr., and a combustion rate of 43 lb. per sq. ft. of projected grate area per hr.

The stoker drive shaft will be driven through a chain drive from an hydraulic, variable-speed motor. The hydraulic motor will be actuated by a fluid pump which in turn will be driven by a built-in, gear-type steam turbine. The driving levers for the clinker grinder rolls will be moved by hydraulic rams. An hydraulic pump, driven by a direct-connected turbine will actuate the rams.

The method of driving the induced draft fans is a particularly interesting feature of this installation. It comprises a relatively small slip ring motor connected to one end of the fan shaft and a constant-speed squirrel-cage motor of larger capacity connected to the other end of the induced draft fan shaft. In operation the fan is started with the small motor. The "start"button of the small motor is pressed when the automatic drum speed regulator is set for the minimum fan speed which is approximately 175 r.p.m. After the fan has accelerated to this speed it is possible, by another push button station, to increase the speed of the fan by cutting out rotor resistance in the smaller slip-ring-motor rotor circuit. This increase in speed may be continued until the top speed of

approximately 350 r.p.m. is reached. At this point the maximum rating at which the smaller machine is capable of carrying the boiler is attained and higher ratings must be carried on the larger motor. Pressing the "start" button for



Sectional elevation of unit.

the larger motor automatically energizes that machine and de-energizes the smaller machine. This larger motor as indicated before is a squirrel-cage machine; consequently any regulation of draft must be by damper control.

In stepping down from ratings which are carried with the high-speed motor, the "stop"button of the high-speed motor is pressed thereby disconnecting this machine. To prevent a dynamic brake action by immediately energizing the small motor a centrifugal governor comes into play and this withholds closing the circuit on the small motor until the fan speed has dropped to approximately 350 r.p.m. At this speed the small motor is energized. If slower speed than this is desired, then the drum controller is operated by means of the slow push button station and the fan speed may be reduced to 175 r.p.m.

Emergency stop push buttons are also included and the pressing of any one of these results in immediately disconnecting the fan whether it is operating on the large or the small motor.

The detailed work of designing the steam generating units has now been practically completed and erection will start in the early part of 1933. The installation is scheduled to be ready for operation by Oct. 1, 1933.

The consulting engineers on this project are United Engineers and Constructors, Inc., Philadelphia.

### Equipment Data for Six Boiler Units

**Boilers**

Type—three-pass sectional header. Heating surface—25,240 sq. ft. Manufacturer—Combustion Engineering Corporation. Soot blowers—Diamond Power Specialty Corp.

**Furnaces**

Of suspended refractory and water-wall construction with partial air cooling. Suspended walls for 3 units by M. H. Detrick Company and for 3 units by American Arch Company.

**Water-Walls**

Plain tube partly covered with integral block. Heating surface—1,032 sq. ft. Manufacturer—Combustion Engineering Corporation.

**Stokers**

Type-multiple retort underfeed. Manufacturer—Combustion Engineering Corporation. Drives—Hele-Shaw hydraulic pumps and motors with Elliott built-in gear turbines for driving pump units—American Engineering Company. Clinker grinder drives—Hele-Shaw hydraulic pump and plunger—American Engineering Company. Turbine for driving hydraulic pump—B. F. Sturtevant Company.

**Fans**

Induced draft—B. F. Sturtevant Company No. 12. Motor drives—Westinghouse Electric & Manufacturing Company. Forced draft—B. F. Sturtevant Company. Turbine drives—B. F. Sturtevant Company. Electrical control equipment—Cutler Hammer, Inc.

**Valves and Gages**

Boiler safety valves—Consolidated Ashcroft Hancock Company; Boiler feed valves and drain valves—Edward Valve & Manufacturing Company; Boiler and water wall blowoff valves—Yarnall-Waring Company; Water columns—Yarnall-Waring Company; Steam non-return valve—Pittsburgh Valve & Foundry Company; Steam gages—Ashton Valve Company; Water column gage glass—Klingerit Company.

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**The Worthington Pump and Machinery Corporation** recently announced the appointment of Hugh Benet as Manager of its Harrison, N. J. Works.

Since 1927, when Mr. Benet became associated with the Worthington organization, he has served as Manager of that company's Holyoke, Mass., Works.

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**Mundet Cork Corporation,** manufacturers of cork products, announces that C. R. Howard has been appointed their distributor at Charlotte, N. C., to cover North and South Carolina. Mr. Howard will carry the full line of insulation, namely, sheet cork, cork pipe covering, cork machinery isolation and cork isolation mats.

# NEW CATALOGS AND BULLETINS

**Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine**

### Boiler Tube Cleaners

"Clean Tubes with Lagonda Tube Cleaners" is the title of a new catalog issued by the Lagonda Mfg. Company. This publication discusses the types of tube cleaners applicable to the various types of boilers and also the care and operation of tube cleaners. The distinct features and details of the numerous types of the Lagonda Tube Cleaners are set forth. The catalog is profusely illustrated. 24 pages, 7¾ x 10¾—The Lagonda Mfg. Company, Springfield, Ohio.

### Heavy Duty Underfeed Stoker

With the unusual title of "Others Too Have Buried It", a new catalog was recently issued describing the Patterson Underfeed Stoker, Heavy Duty Type. This stoker is suitable for application to any type and size of boiler. Although it is commonly applied to steam-power and heating boilers, it is also suitable for process work, dryers, incinerators, etc. Some of the advantages claimed for this stoker are: ram feed, simple in design and rugged in construction. The center-spread of the catalog shows a fine illustration of the stoker with coal burning on the tuyeres. 8 pages, 8½ x 11.—The Patterson Foundry and Machine Company, East Liverpool, Ohio.

### New Fluid Meters

Bulletin No. 300, describing the new line of Bailey Fluid Meters now available, has just been published by the Bailey Meter Company, 1050 Ivanhoe Road, Cleveland, Ohio. This bulletin describes and illustrates the several types of meters which can be furnished, pointing out the many features which make the new line of meters outstanding. Other sections of the bulletin deal with the application and methods of installation of the equipment. Numerous illustrations are included in the bulletin, comprising detailed drawings, diagrammatic sketches, equipment photographs, and chart reproductions in four colors. 24 pages, 7¾ x 10¾.

### New Type Conveyor

"En Masse" Conveying is the title of a catalog just issued by the Stephens-Adamson Mfg. Company. This catalog describes an entirely new type of conveyor, invented in England for handling bulk materials such as grain, coal, chemicals, cement, lime and ore concentrates. Materials are carried in enclosed casing horizontally, up inclines, vertically and around obstructions in a compact, quiescent flow that prevents breakage, degradation and dust. 20 pages, Stephens-Adamson Mfg. Company., Aurora, Illinois.

### Refractory Brick

A new folder has been issued describing Carbex refractory brick. This boiler furnace brick is usually confined to locations where the severest heat conditions prevail, that is, where clinker adhesion, surface erosion and spalling would be most destructive to fire clay. It is claimed that Carbex lining 15 to 35 in. high in the clinker zone along the grate line, around the firebox, including the front wall, will nullify the principal causes of furnace lining failure. 8 pages, 3½ x 6½—McLeod & Henry Company, Troy, New York.

### Steam Trap Book

"The Armstrong Steam Trap Book" is the name of a catalog just published. This comprehensive book can answer practically any question relative to the several steam traps built by the Armstrong organization. The details of design and construction are set forth at considerable length. Special topics: How to Determine Size of Trap Required; Examples; Special Problems: How to Calculate Rate of Condensation: Condensate Drainage Systems; The Need for Individual Traps, etc. 28 pages, 8½ x 11—Armstrong Machine Works, Three Rivers, Mich.

### Surface Condensers

A new bulletin on surface condensers issued by Ingersoll-Rand Company, 11 Broadway, New York, illustrates many of its condenser installations ranging from small units up to those of 160,000 kw. capacity. Features discussed include single and two-pass construction, heart-shaped shell, external air coolers, longitudinal steam distribution, and tube-sheet arrangement. Separate sections are devoted to small condensers, steel-plate condensers, and marine condensers. 36 pages and cover, 8½ x 11.

### Testing Sieves

A new folder has just been issued describing Newark Testing Sieves and U. S. Standard and A.S.T.M. Standard Cornerless Testing Sieves. The folder contains interesting descriptive material, tables, etc. 6 pages, 4 x 9¼—Newark Wire Cloth Company, 351-365 Verona Avenue, Newark, New Jersey.

### Water Column

Catalog WG 1802 describes and illustrates the Yarway Floatless Hi-Lo Alarm Water Column and Se-Sure Inclined Water Gage. The Yarway Floatless Hi-Lo Alarm Water Column depends for its action upon the displacement of solid weights suspended from two levers. When high or low water conditions prevail, the equilibrium of the weights is changed and a different relationship between them results, causing the opening of the single whistle valve and admitting steam to the alarm whistle thus setting it off. The design of the Yarway Se-Sure Inclined Water Gage provides for instant reading of the water level from any position, irrespective of height above fire-room floor. 24 pages and cover, 6 x 9—Yarnall-Waring Company, Chestnut Hill, Philadelphia.

### Wear and Lubricant Tester

"Announcing the Timken Wear and Lubricant Tester" is the title of a publication describing this new Timken product. This tester is designed to test the load carrying capacity or film strength of lubricants, both fluid oils and greases. It is claimed that the Timken tester will enable machinery manufacturers to give the proper lubrication instructions to users of their machines thus still further simplifying lubrication problems. This tester has a wide range of applications since it can be used for the determination of friction or the measurement of wear in addition to the testing of lubricants. 12 pages, 6 x 9—The Timken Roller Bearing Company, Canton, Ohio.

### Welding

"Weld it Well" is the title of a new catalog recently issued. This generously illustrated publication describes the latest developments in welding practice and welder design, and covers many phases of arc welding. The P&H Hansen Electric Arc Welder is described in detail and its features set forth in a large, clear, colored illustration. An Oscillograph record of arc stability and arc recovery, radiographs of welds showing strengths, and illustrations of arc welding design are some of the features of this new catalog. 20 pages, 8½ x 11—Harnischfeger Corporation, 4400 W. National Ave., Milwaukee, Wisconsin.

## NOTICE

**Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to**

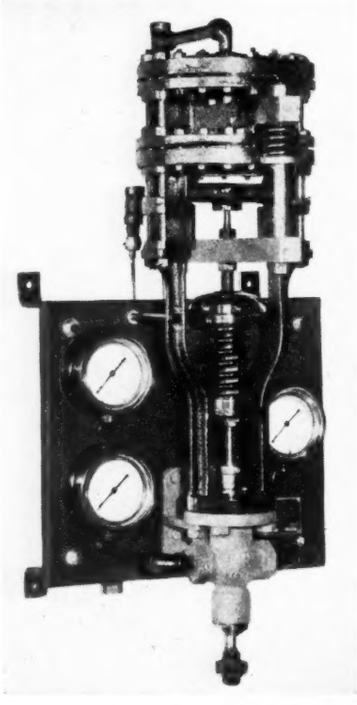
**COMBUSTION**
**200 Madison Ave., New York**

# NEW EQUIPMENT

**of interest to steam plant Engineers**

### Differential Pressure Master Control

The Swartwout Company, 18511 Euclid Avenue, Cleveland, Ohio, has developed and placed on the market a new control device which has been called Type "CPDM" Differential Pressure Master Control. This device is used to maintain a differential between pressures which are applied to the upper and lower diaphragms. An auxiliary motive force, which may be air, water, steam or oil, is then used to operate a single valve, a group of valves, motor rheostats, cutout switches or any other desired control



equipment. This device will be on display at the Swartwout Company exhibit at the New York Power Show.

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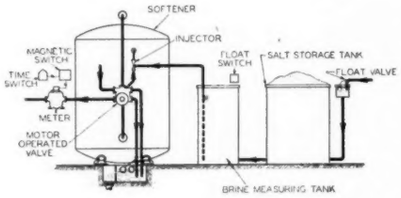
### Automatic Water Softener

A new fully automatic industrial zeolite water softener has just been announced by The Permutit Company, 440 Fourth Avenue, New York. This softener, which will be shown at Grand Central Palace, Booth No. 348, during the New York Power Show, December 5th to 10th, eliminates the errors due to the human element and conducts all of the operations of softening and regeneration with machine-like regularity and precision.

By a combination of a meter operated switch and electric controls with a motor driven Permutit single valve, each operation of the water softener is conducted under such precise control that the highest efficiency results. Briefly, at the end of the softening run, the meter actuates the electrical controls which carry through the following steps: cutting the softener out of operation; backwashing it for a regulated period so as to secure thorough cleansing; admitting a carefully regulated amount of saturated salt brine so as to assure thorough regeneration without wastage of salt; rinsing out the hardness salts to waste with the minimum amount of rinse water; and throwing the softener back into service thus placing it again under control of the meter, which governs the volume of water to be softened during the softening run and initiates the start of the next regenerating cycle.




Not only may the new models be had in the fully automatic type but it is also a relatively simple matter to apply the automatic control to existent downflow softeners thus converting manual to fully automatic operation.

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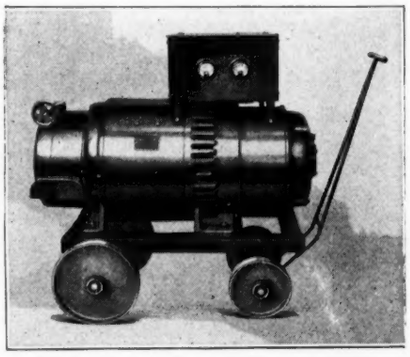
### Arc Welders

The Harnischfeger Corporation, 4400 W. National Ave., Milwaukee, Wisconsin, have improved and revised their line of P&H Hansen Arc Welders. A new magnetic bridge, and a unique



short circuit winding are claimed to have greatly extended the welding range, and further improved arc recovery and arc stability.

Single operator electric motor driven types of arc welders are produced in 100, 200, 300, 400, 600 and 800 ampere sizes. Variants in stationary and portable types are designed to operate on either alternating or direct current. Up to 300 ampere size units have the motor and generator mounted as a single unit to form a compact two-bearing machine. The larger sizes are four-bearing units, the generator and motor are direct coupled and mounted on a welded steel base.

Welders designed to operate on alternating current have an enclosed push button starter. Protection against the extremes of under voltage and overload is amply provided for. Direct current units have a starter with no voltage release and protection against overloads. All P&H Hansen Welders are claimed to be dust and moisture proof, assuring constant operation under severe conditions.

Several types of welders are available, including "Two-Operator" Units, Gasoline Engine Driven stationary or portable units, beside a complete line of Arc Welders for every purpose.

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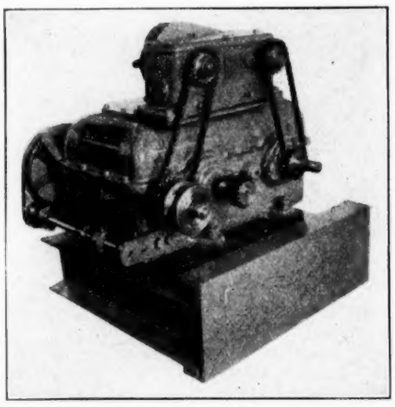
### Variable Speed Transmission with Automatic Time Cycle Control

After much experimental work, the Link-Belt Company, 910 S. Michigan Avenue, Chicago, Illinois, has placed on the market a variable speed transmission with automatic time cycle control.



The unit illustrated (the second one built) is a Link-Belt P. I. V. Gear, with special speed reduction unit mounted on top and connected by roller chain drives to the Gear's constant speed shaft (at right) and to its control screw (at left), the complete mechanism being mounted on a fabricated steel base for bolting to the frame of the machine to be operated.

The constant speed shaft of the Gear is direct-connected through a coupling, and operates at 751 r.p.m. The variable speed or output shaft has a starting speed in the cycle selected, of from 500 to 1100 r.p.m. A silent chain drive connects this shaft to the main shaft of the machine controlled.

To obtain the speed changes required, the control screw must turn .00594 r.p.m. under maximum conditions, and .000408 r.p.m. under minimum conditions; and it, therefore, became necessary to apply the aforesaid special reduction unit to the normal P. I. V. Gear unit.

This special reduction unit has a fixed ratio of 360,000 to 1, but the change gears encased on the back of it, permit a maximum ratio of 1,380,000 to 1, and a minimum ratio of 94,737 to 1. When the control screw of the Gear is operating at minimum speed, the total reduction from the constant speed shaft of the Gear to the control screw, is 1,840,000.

When a desired combination and setting have been determined and must be repeated, a special indicator and limit stop are used. From the far end of the control screw a gear drive operates the indicator shaft, on which is a traveling indicator pointing to a scale of the width of the Gear box. The locking nut can be set to permit an exact return manually to the starting speed.

The double hand wheel is used not only to obtain the starting position required, but also for re-setting to repeat a cycle. While the gear and timing mechanism are operating, the hand wheel clutch is disengaged from the roller chain wheel in order to make the return setting. One hand wheel is for ordinary adjustment, and the second one for fine adjustment.

A further function incorporated in the hand wheel is a series of pins and springs so set as to slip, in case the Gear is permitted to run beyond its cycle and the limit of adjustment or movement of the control mechanism and parts of the Gear.

A selection chart enables the user to determine the ratio of change gears to employ on the special reducer unit, for the necessary combination of speed, percentage of speed change, and time.

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## Differential Draft Control System

A new Differential Draft Control System has been developed and placed on the market by the Mason Regulator Company, 1190 Adams Street, Boston, Massachusetts. This new controller is of the instrument type and regulates the amount of air passing through the furnace in accordance with the natural draft of the stack and also the quantity of fuel consumed. In order to accomplish this the Mason instrument controls the feed of forced, or induced draft

blowers, the inlet, up-take or stack dampers, or any other suitable means for controlling the flow of air to the furnaces.

This new draft control instrument, like most other temperature and pressure control instruments, is operated by compressed air. It is very sensitive and even the slightest variation in draft differential is sufficient to control the blowers or dampers so as to maintain perfect combustion under varying conditions.

It is claimed that the Mason Draft Control System will effect definite savings in fuel and also remove the smoke nuisance.

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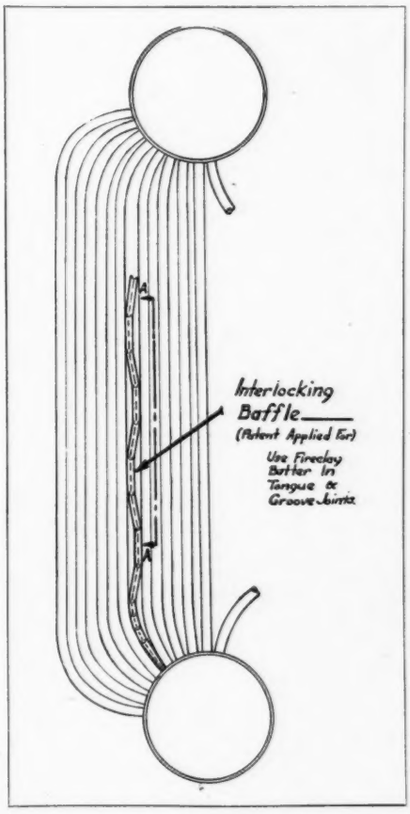
## Vertical Baffle

The Power Plant Efficiency Co., 155 E. Market Street, Indianapolis, Indiana, has recently introduced a vertical baffle




partition which is made of their Interlocking Baffle Tiles.

The tiles used have tongue and groove horizontal joints and lap vertical joints. This design tile serves bent-tub type boilers, totalling over 2,000,000 boiler horsepower.

The new baffle partition is made of tiles not over 2 in. thick, which provides minimum weight and gives a quality of flexibility to the partition. The elimination of a rigid structure is assured by the tile-lap vertical joints and by the clearance provided for shrinkage of material, expansion and contraction.

It is claimed that this design of tile joint effects insulation of heat and stops draft and gas leaks.

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## Endless Belting

Another great advance in the field of transmission belting has just been announced by J. H. Connors, vice president, The B. F. Goodrich Company, Akron, Ohio.

Progress in the rubber belting field has always been confronted with the stumbling block of those industries where it has been impossible heretofore

to install factory made endless belts, or to use those laced with any of the conventional types of fasteners.

These fields require belts to be made endless in their plants after being applied to the machine on which they are called upon to operate. Goodrich has solved this problem. After four years of laboratory and field experiments Mr. Connors now announces a new belt and a simple inexpensive outfit that gives plants heretofore unable to use rubber belting an opportunity to reduce their transmission costs by use of this new product and method.

The new belt is named "Highflex Junior." It is built up of a greater number of plies of a specially woven fabric designed primarily to give the proper characteristics so necessary when transmission belting is to be spliced endless right on the machine.

This new product is not to be confused with its parent "Highflex" announced several years ago and since then a major product of the belting field. Highflex Junior is made only in widths 6 in. and under.

To develop this new economical, trouble free belting program, Goodrich laboratories had to develop a special cement and tie gum for making the splice. When used with Highflex Junior, according to instructions, the manufacturers claim it will result in a long lived economical belt joint.

As a necessary adjunct of this program a line of low priced, electrically heated, automatically controlled portable electric vulcanizers was developed by the James C. Heintz Company of Cleveland.

A light template for laying out and stepping down the ends of the belt so a perfect fit can be obtained, along with the necessary hand tools, complete the equipment. It is portable, easy to handle, and accompanied by complete concise instructions makes an ideal setup.

Although applicable to many plants this new development is expected to be particularly welcome in the milling and textile industries.

# BOOKS

## 1—Water Analysis

For Sanitary and Technical Purposes
By Herbert B. Stocks

135 Pages $3.50

Public health officers, city chemists and those engaged in the study of this branch of analytical work will be interested in this new edition of a book which has long been a standard in this country and England on the subject of the methods adopted for the analysis of water for sanitary and technical purposes. It has been completely revised, rearranged and added to by W. Gordon Carey.

Modern developments have necessitated new sections dealing with hydrogen ion concentration, the determination of free chlorine in chlorinated water, and the determination of iodides. A section on simple bacteriological methods is included in this edition, and should prove of service to those who use this book.

## 2—World Economic Survey 1931-32

327 Pages $2.50

The first *World Economic Survey*, issued by the League of Nations, gives a comprehensive review of the development of the world depression up to the middle of January, 1932.

The first chapters set forth the elements of instability in the post-war economic situation, movements of population and of industrial production, the increasing rigidity of economic organization, the shifts in international indebtedness and trading relationships resulting from the war. Special stress is laid upon the importance of movements of capital from one country to another and upon the relation of the credit expansion of 1925-29 to such capital movements.

The main body of the Survey consists of an analysis of the developments of the depression in its various aspects:—the disorganization of production, prices and trade; the difficulties that have arisen in the balancing of international accounts; the growth of unemployment; the strain on the public finances of most countries; and the drift of commercial policy towards increasing measures of trade restriction. A final chapter surveys the position that existed in July, 1932, and the various international measures under consideration as a means of escape from the crisis.

## 3—Science in Action

By Edward R. Weidlein
and William A. Hamor

310 Pages Price $3.00

The authors, both connected with the Mellon Institute of Industrial Research, present in clear language, a sketch of the value of scientific research in American Industry. This interesting and readable book is planned to give the business man, engineer and scientist a comprehensive picture of the place of science in industry—the means and methods of industrial research, the results achieved, the important factors in procedure and the choice of workers.

## 4—Pulverized Fuel Firing

By Sydney H. North

204 Pages Illustrated Price $2.25

The author of this book, an Englishman, briefly reviews the history of pulverized fuel as a prelude to a discussion of its development to the present day. Contemporary designs of furnaces, burners, feeders, pulverizing mills, driers, dust collectors, etc., are described and illustrated, as are actual installations in America and Europe which exemplify the trends of practice. Chapters are devoted to the combustion of pulverized fuel and its use in connection with Lancashire boilers, marine boilers and in metallurgical furnaces.

## 5—Steam Power Plant Engineering

By G. F. Gebhardt

1036 Pages Price $6.00

One of the truly standard reference books on mechanical engineering. It is a necessary part of the equipment of everyone who has to do with steam-power plant engineering.

## 6—Mechanical Engineers' Handbook

By R. T. Kent

2247 Pages 10th Ed. Price $6.00

Designer, power-plant engineer, shop-superintendent, heating and ventilating engineer, hydraulic engineer, building constructor, foundryman, automotive engineer, will find this handbook to be a complete reference book covering their field and many others. "Kent" is more than a book, it is a complete library of engineering practice.

## 7—Hydraulic (4th Edition, Revised 1932)

By E. H. Lewitt, B. Sc.

384 Pages 8½ x 5½ Price $3.00

Deals from first principles with the theory of hydraulics and its application. This is primarily a student's textbook and no attempt has been made to deal with design problems, which are beyond the scope of the engineering degrees. Numerous worked-out examples from past B. Sc. examinations of the University of London are included; also a number of exercises, with answers, at the end of each chapter. A large amount of new matter has been added to the former edition of this book, giving the results of recent researches on the viscous flow of fluids.

## 8—Nature of a Gas

By Leonard B. Loeb

153 Pages 6 x 9 $2.50

This book presents in an exceptionally clear manner the essential facts covering atomic and gaseous structure. It will serve as an excellent introduction to engineers and industrial technicians on the electrical properties of a gas as a preparation for more advanced and technical monographs on the subject. The volume is brief, concise, but gives all necessary data on the breakdown of solid and liquid dielectrics.

The book is developed in an interesting and logical manner, and is the only compilation of reliable data on electrical properties of gases. It will appeal to physicists, chemists, electrical engineers and all those who work on electrical problems in which a gas is used as an insulator or conductor, or where its presence modifies the main phenomenon.

## 9—A Handbook of English in Engineering Use

308 Pages By A. C. Howell Price $2.50

Here is a real up-to-the-minute handbook that should be on the desk of every technical writer. Most engineers today have occasion to do considerable writing and for those who have some doubt as to their ability to express themselves clearly, accurately and in acceptable form, Professor Howell's book will be of very definite value. The author takes a very practical point with regard to the engineer's professional use of language. Chapters are devoted to word usage and idioms, sentence and paragraph structure, composition, punctuation and the mechanics of writing and grammar. Examples cover letters, reports and technical articles.

## 10—Steel Construction

450 Pages 8¼ x 5¼ Price $2.00

The 1932 Handbook of the American Institute of Steel Construction combines the information contained in their previous publications. Considerable new material has been added, and the data regarding the new sections recently produced by the rolling mills is complete up to the minute of publication. The arrangement is excellent. The fact that there is complete information on one page for each size section saves not only time but the possibility of error. Very attractively bound and indispensable in the office of anyone in the steel business.

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# for CHRISTMAS

**The books described on these pages are especially recommended as Christmas gifts for engineers because they are recognized as authoritative treatments of the subjects covered.**

***A discount of ten per cent will be allowed on all orders received during December for the books listed below.***

### 11—Mechanical Engineers' Handbook

By Lionel S. Marks

2265 pages Price $7.00

It is unnecessary to say a great deal about Marks' handbook. The third edition of this great reference book has been thoroughly revised in all parts, bringing it up to date in both practice and theory. Important new sections include vibration problems—refractories, high temperature carbonization of coal and gas making—low-temperature carbonization of coal—industrial combustion furnaces—electric industrial furnaces.

### 12—Thermodynamics (Third Edition)

By J. E. Emswiler

347 Pages Size 6 x 9 Price $3.00

The first edition of this book, published in 1921, was intended to present the subject matter with especial regard to the student's viewpoint. The ready acceptance of the text by teachers in engineering colleges all over the country testified to the success of the author's efforts.

In this new edition, the third, a considerable part of the text has been rewritten, much new material introduced, and several new problems added at the ends of the chapters.

### 13—Industrial Gas Series—Combustion (Third Edition)

207 Pages Price $2.00

Although a third edition, this book, prepared under the supervision of the Committee on "Combustion" of the Industrial Gas Section of the American Gas Association, has been so completely revised both with respect to content and treatment that it is in reality a new book.

The following chapter headings give a good idea of the scope covered by this book: Heat and Its Measurements; Gas Volume and Pressure; Chemistry of Combustion: Thermal Capacity; Heat Transfer; Combustion Data of Commercial Gases; Atmospheric Burners; Industrial Combustion Equipment; Temperature Control; Heat Salvage Methods; Gas Analysis; Fuel Comparisons.

### 14—Steam Tables and Mollier Diagram

By Joseph H. Keenan

Price $2.00

These new Steam Tables, extending to a pressure of 3500 lb. per sq. in. and a temperature of 1000 deg. fahr., were developed from the latest experimental data secured by investigators in laboratories of Europe and those of the United States. The Symbols used in this work are taken from the latest test prepared by the A.S.A. Sub-Committee for Heat and Thermodynamics. A large copy of the new Mollier Diagram (23" x 34") is also included.

### 15—Finding and Stopping Waste in Modern Boiler Rooms

By H. B. Cochrane

808 Pages Price $3.00

As a handbook on fuels, combustion, heat absorption, boilers and feed-water, this volume is eminently practical and useful. Every steam plant engineer should have a copy.

### 16—Handbook of the National District Heating Association—1932 (Second Edition)

538 Pages 6 x 9 Price $5.00

This handbook, which is essentially an encyclopedia of district heating, will be of interest and value not only to those who are actively engaged in this work but also to those who desire to familiarize themselves with this important industry.

### 17—Behemoth: The Story of Power

By Eric Hodgins and F. Alexander Magoun

354 Pages 6½ x 9 Price $3.50

Setting out to prove no theses and taking no sides in the quarrels centering around our machine civilization, Eric Hodgins and F. Alexander Magoun have told in BEHEMOTH: The Story of Power, the first complete story of this age of power and of its creation out of the vague and confused beginnings that followed the close of the Middle Ages. Combining vivid history and biography with sound science, Mr. Hodgins and Mr. Magoun paint a picture of the rise of power from primitive days, when muscles were the only power machines, down to the modern marvels of machinery, which cram 100,000 horsepower into the size of a modern five-room apartment. BEHEMOTH is the story of an age, entertainingly told in terms of the men who created it.

### 18—American Machinists' Handbook (Fifth Edition)

By Fred H. Colvin and Frank A. Stanley

1140 Pages 4 x 7 Price $4.00

Every section of the Fifth Edition of this well-known manual has been thoroughly revised—some of them have been practically entirely re-written. A great deal of the new material is in the shape of data and methods which have been developed and are now being used in some of the world's leading manufacturing concerns. Another feature is in the insertion of special tables and diagrams to help in estimating and selecting proper equipment for various jobs. Obsolete material has been weeded out making the book 100 per cent usable and up-to-date.

### 19—Power Plant Management

By Walter N. Polakov

171 Pages Price $2.00

This book offers information of considerable value to those concerned with the management or supervision of power plants, and will help to solve many problems.

### 20—General Engineering Handbook (First Edition)

Editor-in-Chief: Charles Edward O'Rourke

922 Pages Price $4.00

The plan for this handbook, according to the editor-in-chief, was conceived in the belief that a great amount of fundamental engineering data could be assembled in a compact pocketbook of not over 900 pages, which would be valuable as a ready reference and hand companion for practicing engineers and for students. The purpose is to supply a compact reference work of important fundamentals for all engineers. Accordingly, there are 31 sections, each section dealing with one general subject. Six of these sections contain material which is of importance to all engineers; others belong in the fields of civil, mechanical, electrical engineering, etc.

### 21—The Book of Metals

By Donald Wilhelm

332 Pages Price $4.00

This book is typical of several others published in recent years in that it discloses the principles and practices of a thoroughly technical industry in such form that it is just as easily assimilated by the layman as by the technician.

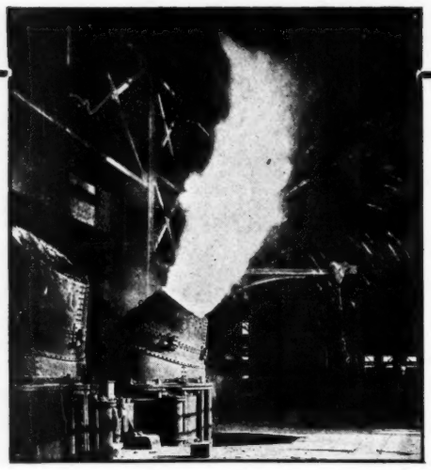
This book should be read by everyone who is interested in knowing the whys and wherefores of the principal metals, and even by those who are perhaps fairly well informed in these matters but who would like to have a glimpse into the great steel laboratories of today so that they might know more of the innumerable alloys which are being developed there to meet the future needs of industry.

### 22—Pulverized Fuel

By W. F. Goodrich

215 Pages Price $5.00

Contents: Pulverized Fuel—its origin and history; United States Practice; French and British Practice; Design, Equipment and Operation; Fuels Suitable for Use in Pulverized Form; The Future of Pulverized Fuel. Contains 88 illustrations, 16 tables.



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# Boiler, Stoker and Pulverized Fuel Equipment Sales

***As reported by equipment manufacturers to the Department of Commerce, Bureau of the Census.***

## Boiler Sales

Orders for 439 boilers were placed in September by 72 manufacturers

| | Number | Square feet |
|---|---|---|
| September, 1932 | 439 | 461,177 |
| September, 1931 | 846 | 587,496 |
| January to September (inclusive, 1932) | 2,697 | 2,687,169 |
| Equivalent period, 1931 | 6,014 | 5,133,685 |
| Total, 1931 | 7,508 | 6,327,262 |

NEW ORDERS, BY KIND, PLACED IN SEPTEMBER, 1931-1932

| Kind | September, 1931 | | September, 1932 | |
|---|---|---|---|---|
| | Number | Square feet | Number | Square feet |
| Stationary: | | | | |
| Water tube | 54 | 219,759 | 39 | 278,865 |
| Horizontal return tubular | 60 | 73,421 | 19 | 31,276 |
| Vertical fire tube | 48 | 10,609 | 33 | 10,729 |
| Locomotive, not railway | 6 | 4,497 | 4 | 2,590 |
| Steel heating | 640 | 249,766 | 326 | 120,569 |
| Oil country | ... | ..... | 1 | 1,010 |
| Self contained portable | 30 | 27,329 | 15 | 14,378 |
| Miscellaneous | 8 | 2,115 | 2 | 1,760 |
| Total | 846 | 587,496 | 439 | 461,177 |

## Mechanical Stoker Sales

Orders for 174 stokers totaling 19,592 hp. were placed in September by 55 manufacturers

| | Installed under | | | |
|---|---|---|---|---|
| | Fire-tube boilers | | Water-tube boilers | |
| | No. | Horsepower | No. | Horsepower |
| September, 1932 | 117 | 14,270 | 57 | 15,322 |
| September, 1931 | 279 | 40,570 | 46 | 14,509 |
| January to Sept. (inclusive, 1932) | 665 | 87,967 | 313 | 121,615 |
| Equivalent period, 1931 | 1,371 | 181,502 | 462 | 151,929 |
| Total, 1931 | 1,889 | 252,571 | 574 | 187,507 |

## Pulverized Fuel Equipment Sales

Orders for pulverizing equipment for the month of September not reported up to the time of going to press.

| | STORAGE SYSTEM | | | | | | |
|---|---|---|---|---|---|---|---|
| | Pulverizers | | | | Water-tube Boilers | | |
| | Total Number | No. for new boilers, furnaces and kilns | No. for existing boilers | Total capacity lb. coal per hour for contract | Number | Total sq. ft. steam generating surface | Total lb. steam per hour equivalent |
| September, 1932 | .. | .. | .. | .... | .. | .... | ..... |
| September, 1931 | .. | .. | .. | .... | .. | .... | ..... |
| January to September (inclusive, 1932) | .. | .. | .. | .... | .. | .... | ..... |
| Equivalent period, 1931 | .. | .. | .. | .... | .. | .... | ..... |
| Total, 1931 | 8 | 7 | 1 | 250,000 | 37 | 126,471 | 1,797,000 |
| | DIRECT FIRED OR UNIT SYSTEM | | | | | | |
| | Pulverizers | | | | Water-tube Boilers | | |
| September, 1932 | .. | .. | .. | .... | .. | .... | ..... |
| September, 1931 | .. | .. | .. | .... | .. | .... | ..... |
| January to September (inclusive, 1932) | .. | .. | .. | .... | .. | .... | ..... |
| Equivalent period, 1931 | .. | .. | .. | .... | .. | .... | ..... |
| Total, 1931 | 72 | 52 | 20 | 450,960 | 58 | 417,327 | 4,455,585 |
| | | | | | Fire-tube Boilers | | |
| September, 1932 | .. | .. | .. | .... | .. | .... | ..... |
| September, 1931 | .. | .. | .. | .... | .. | .... | ..... |
| January to September (inclusive, 1932) | .. | .. | .. | .... | .. | .... | ..... |
| Equivalent period, 1931 | .. | .. | .. | .... | .. | .... | ..... |
| Total, 1931 | 35 | 1 | 24 | 39,300 | 37 | 59,761 | 347,100 |